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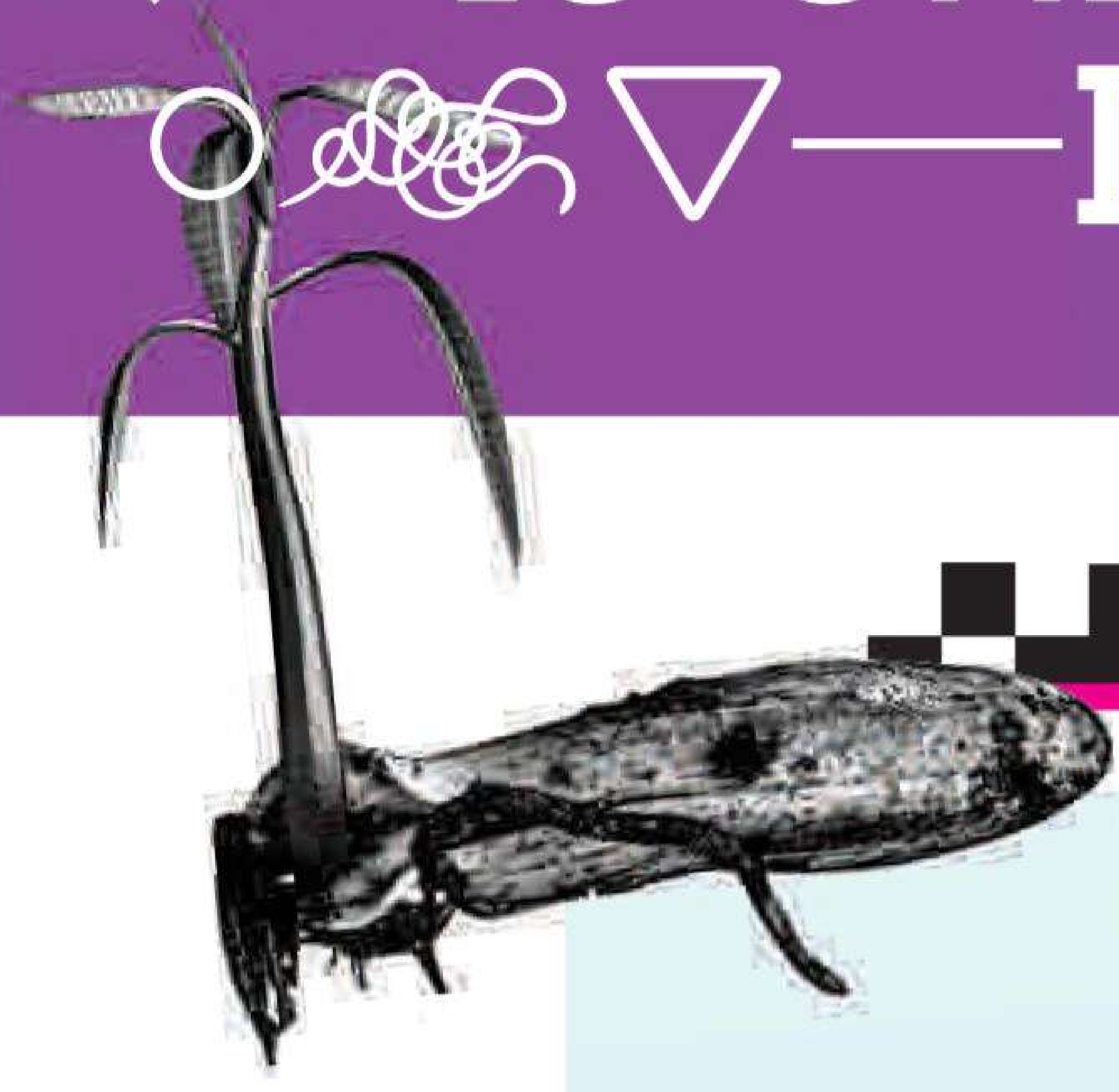

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Weekly

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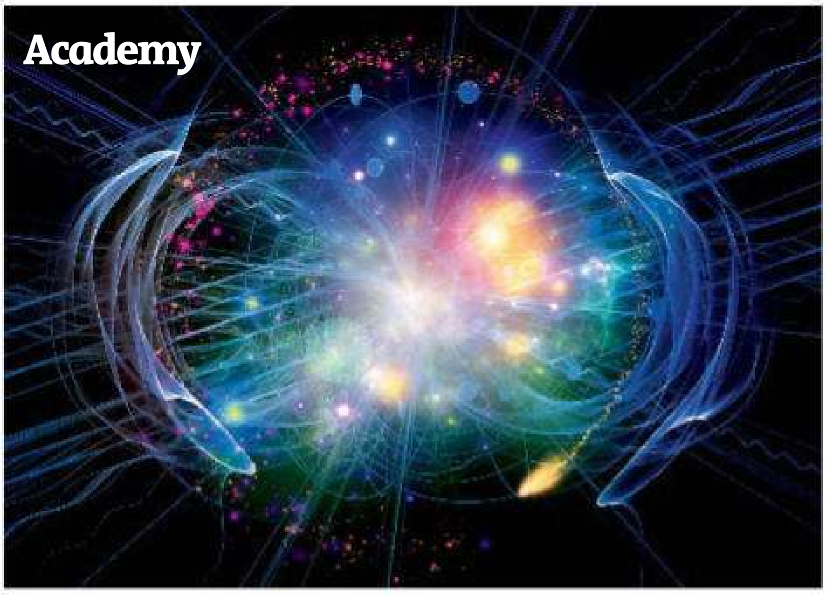

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MARK O'HARA

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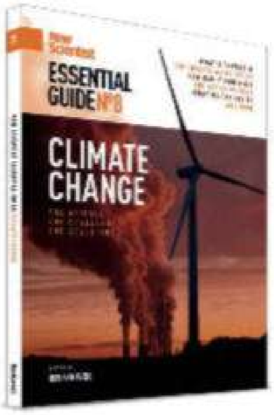
> **"New ways to fight superbugs are in the works, including DNA origami weapons"**



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Hitting the targets

Health guidelines are far from perfect, but they might just save us from ourselves

LIVING to a ripe old age owes a fair amount to luck, but if science can tell us anything about health, it is that our judgement matters, too. The way we live our lives and the way we treat our bodies can make a huge difference to our chances of having a long and healthy life.

This is the basic message encoded in the generic health targets that we all carry in our heads: five pieces of fruit or veg a day, 8 hours of sleep, 10,000 steps, 2000 calories and so on.

Yet on closer inspection, many of the best-known nuggets of health advice owe more to marketing and folklore than they do to science. The 10,000 steps per day that so many people aim to take seem to have been largely plucked from nowhere. Even dentists can't tell you why they recommend brushing specifically for 2 minutes, twice a day, as our feature on page 38 reveals.

To make matters worse, even advice that stems from decades of research comes from epidemiological studies, which follow large numbers of people over many years. Translating this kind of data into one-size-fits-all advice is notoriously difficult for the simple reason that we aren't all the same.

> "Many nuggets of health advice owe more to marketing and folklore than they do to science"

The number of hours you need to sleep for can vary by 7 hours depending on your age, for example. Then there is the ideal number of steps, which differs depending on whether you are hiking up the side of a mountain or ambling around a shopping mall. And since science's work is never done, even solid health advice can, and does, change.

With this much complexity, it is tempting to just ditch living by numbers. Yet targets do have a part to play in health education. Even though fewer than a third of UK adults actually manage to consume five portions of fruit and vegetables a day, the average child at primary school can recite the guideline, so at least has internalised the message that eating plants is good for you.

And of course, given that our brains are wired to choose instant gratification over a vague promise of better long-term health, even imperfect advice is better than none. ▮

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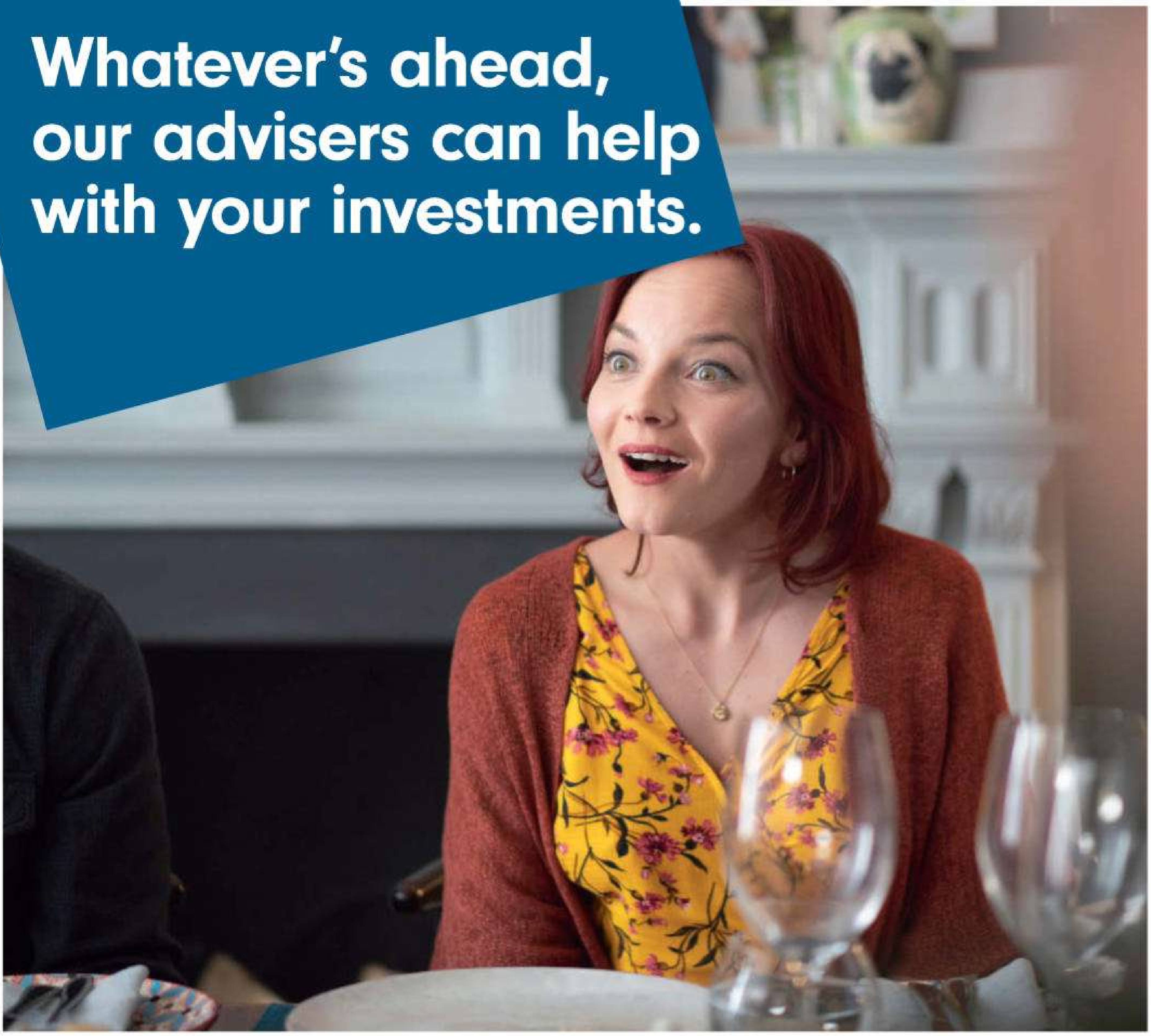

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A pupil in England gets tested prior to returning to school

Coronavirus

School surge warning

Any efforts to vaccinate 12 to 15 year olds may be too late to prevent a wave of infection in England, reports **Michael Le Page**

THE UK government was expected to soon give the go-ahead for vaccinating 12 to 15 year olds in England as *New Scientist* went to press. But with children already back at school, this may come too late to prevent a surge in cases. Rising infection rates have already been seen in the US and Scotland following the start of term.

"Vaccination, even if started now, would be insufficient to control the surge from schools re-opening in September," says Deepti Gurdasani at Queen Mary University of London.

In the US, cases in children have increased fivefold, rising from 38,000 in the week ending 22 July to nearly 204,000 by 26 August, according to the American Academy of Pediatrics. The ages used to define "children" vary from state to state.

In Scotland, where children returned to school in mid-August, the number of reported cases in all age groups has soared to the highest levels since the pandemic first began. On 6 September, 7065 new cases were reported.

Not all experts think the return to school is the main culprit, however. "Scotland is definitely seeing a surge in infections at present, though the rate of increase has slowed, not sped up, when you would have expected to start to see any impact of schools going back," says Paul Hunter at the University of East Anglia, UK.

Several countries, including the US, France, Italy, Spain and the Netherlands, are already vaccinating children aged 12 and over. However, in the UK only those aged 16 or over are being routinely vaccinated.

On 3 September, the UK's Joint Committee on Vaccination and Immunisation decided against recommending extending the vaccination programme to children aged 12 to 15 who don't have underlying conditions or vulnerable family members.

The committee concluded that the health benefits children gain from vaccination are greater than the potential known harms. However, it ruled that those health benefits aren't great enough to justify mass vaccination.

This decision is controversial. Gurdasani thinks the committee is underestimating the health risks that covid-19 poses to children. An analysis by her and her colleagues concluded that the benefits of vaccination greatly outweigh the risks. Other countries have approved vaccines for 12 to 15 year olds following analyses with similar conclusions, says Gurdasani. "I think all evidence suggests that vaccination should be offered to this age group."

Ministers have indicated they are keen to authorise a wider roll-out of vaccines. The government has asked the UK's chief medical officers to review the wider benefits of vaccinating this age group, such as minimising school absences and helping protect older and vulnerable people. An outcome is expected imminently.

Even if the review gives the go-ahead for vaccinating 12 to 15 year olds, it would probably be at least several months before most are fully vaccinated. In the meantime, there will be widespread infections and disruptions to learning in England as children return to school, not least because the measures being taken to prevent the spread of the coronavirus are inadequate, a group of scientists and educators, including Gurdasani, have warned.

In an open letter to the UK education secretary, Gavin Williamson, in the *BMJ* on 3 September, the group recommended nine measures to protect children and wider society, including wearing masks (which is mandatory in schools in Scotland) and improving ventilation in schools in addition to vaccination.

"We need multi-layered measures, and we need them urgently," says Gurdasani. ▮
Additional reporting by Sam Wong

Climate change

Keep it in the ground

Latest figures show just how drastic our rejection of fossil fuels must be in order to remain below 1.5°C of warming, says **Adam Vaughan**

HHAKIM/GETTY IMAGES

Only 58 per cent of oil can be extracted if we want to limit warming

ENERGY companies and nations must leave nine-tenths of Earth's coal and almost two-thirds of its oil and gas in the ground if the world is to hold temperatures to below 1.5°C of global warming, a target beyond which climate change's impacts are dangerously amplified, researchers have calculated.

Their analysis of which fossil fuel reserves are effectively "unextractable" if we are to meet the Paris Agreement temperature pledge makes the situation look dire for petrostates. Globally, oil and gas production must fall by 3 per cent a year to meet the target.

"We're painting quite a bleak picture for the future of the global fossil fuel industry," says James Price at University College London (UCL), who was part of the team behind the analysis. Price and his colleagues built on an influential 2015 study on how much of the world's coal, oil and gas reserves must go unused to stay under 2°C of warming, but this time looked at the 1.5°C goal.

The researchers assumed a "carbon budget" that was about half the size of the earlier study's, allowing the world to emit just 580 billion tonnes of carbon dioxide from fossil fuels between 2018 and 2100. They then updated energy system models to reflect the falling cost of renewables and calculated the carbon within global fossil fuel reserves using data from BP, the International Energy Agency (IEA) and others (*Nature*, DOI: 10.1038/s41586-021-03821-8).

"A key output is we see near a doubling of unextractable oil reserves," says study author Dan Welsby, also at UCL, meaning that much more must go unused to remain under 1.5°C instead of 2°C. For a 1.5°C future, 89 per cent of coal, 58 per cent of oil and 59 per cent of gas must stay in the ground by 2050.

However, the researchers say those figures are probably an underestimate. The first reason is that they only modelled scenarios with a 50 per cent chance of hitting 1.5°C. "You wouldn't get on a plane if you had a 50 per cent probability [of making it]," says Welsby.

Secondly, the modelling is based on relatively high amounts of CO_2 being removed from the atmosphere – about 6 billion tonnes of CO_2 a year – to meet the temperature target. The technology to do this is still in its infancy, but even assuming it is developed in the coming years, the team was unable to model a scenario with a 66 per cent chance of hitting 1.5°C without resorting to "magic" amounts of CO_2 removals.

89%

Proportion of coal we must not use to avoid 1.5°C of warming

"There's a good likelihood the rates of decline are going to have to be even larger, and the total amount of carbon that's going to stay in the ground is also going to be larger. I feel that's quite a stark outcome," says Price. "It really puts into stark relief just how challenging conditions will be for countries that are reliant on [revenues] from oil and gas."

The global figures mask regional differences. One similarity with the 2015 study is that Canada and Venezuela both have to leave an above average amount of oil reserves unused while the Middle East is more akin to the global average. But because of the sheer size of its oil and gas reserves, "that translates into huge volumes left in the ground", says Welsby.

Some oil companies, such as BP, have cut their future oil and gas plans as they attempt to transition to low-carbon energy. Earlier this year, a major report by the IEA suggested no new oil and gas wells should be drilled if the world is to cut emissions to net zero by 2050. However, many national oil and gas companies, such as Qatar Petroleum, plan to grow production. "We need to reverse course. Where we are now is a long way away from where we need to be," says Welsby. ▮

Carbon emissions

CO_2 maps reveal climate impact of commuting

Sian Williams Page

HIGH-RESOLUTION maps of carbon emissions have revealed how our day-to-day patterns of behaviour, such as commuting, affect the release of greenhouse gases, possibly helping governments see the impact of green policies.

Zhu Liu at Tsinghua University in Beijing, China, and his colleagues combined data from various sources to provide daily global maps of carbon dioxide emissions down to a 10-kilometre resolution.

The researchers used country level emission inventories, data from industrial sites and power plants, satellite measurements of nitrogen dioxide and modelling estimates to create the maps.

This allowed them to assess differences between weekend and weekday carbon emissions from ground transportation. They found that emissions fall at the weekend due to a lack of commuters (arxiv.org/abs/2107.08586).

The weekend-weekday difference was smaller in 2020 compared with 2019 due to lockdowns and home-working policies implemented during the coronavirus pandemic. Covid-19 has reduced weekday carbon emissions, says Liu, making the "lifestyle of weekdays more like weekends".

Liu and his colleagues plan to update the data set regularly, giving a near-real-time picture of how changes in policies affect emissions.

Ajay Gambhir at Imperial College London says the picture revealed by this kind of mapping could potentially sway governments towards encouraging long-term flexible working patterns to help meet climate targets.

"It can often take years to see what the impact of a particular policy might be in terms of emissions reductions," he says. "It might well be that this kind of data is a countervailing force." ▮

Fossil fuels

Battle over new UK coal mine puts climate commitments to the test

Adam Vaughan

THE fate of the UK's potential first deep coal mine in 30 years will be fiercely debated at a public inquiry this week, in a big test of new fossil fuel projects as nations are pushed to ramp up net-zero goals.

The mooted Woodhouse Colliery near Whitehaven, Cumbria, has escalated from a local planning issue to a national one with global ramifications as the UK prepares to host the COP26 climate summit in November.

Supporters say the mine will provide desperately needed jobs for the region and displace coal imports. Critics highlight the carbon dioxide emissions from coal and say it risks undermining the crucial climate conference.

The mine proposed by West Cumbria Mining (WCM), which is backed by an Australian private equity group, would produce about 2.8 million tonnes of coking coal a year, which is used in steel-making, not burned for power. The latter has been almost eliminated in the UK, but decarbonising steel-making is seen as a tougher task.

Normally, planning approval would be a decision for a local authority – Cumbria County Council in this case, which has already given the go-ahead three times. However, amid an outcry over the climate impact of the mine, the UK government on 11 March said it would instead make the call to block or allow it. A 16-day public inquiry began on 7 September and will play a key role in a government decision expected early next year.

"Our law is really not clear on whether the coal mine is legal or not," says Rebecca Willis at Lancaster University in the UK. The UK's national planning policy is to block permission for new coal extraction by default, but allows exemptions if developments are "environmentally acceptable" or provide enough local benefits to outweigh wider impacts.

WCM says emissions resulting from the operations of the mine itself will be "net zero carbon" from "day one". But emissions from using the coal, not from mining it, are the far bigger impact. The coal's use would emit greenhouse gases equivalent to 420 million tonnes of CO_2 if the mine operates for 50 years. Globally that may seem small, at about 1 per cent of humanity's annual emissions. But it isn't insignificant: it is on a par with total UK emissions last year.

"We're principally opposed to the mine because the coal it produces will really increase global carbon emissions just at the time scientists have produced their greatest warning yet," says Estelle Morris at environmental campaign group Friends of the Earth, referring to the recent report by the Intergovernmental Panel on Climate Change (IPCC). "It's a dangerous thing to be contemplating at this stage."

Morris rejects the idea UK steel-makers need the coal, arguing the industry is already shifting away from it. WCM has focused on the benefits of UK steel-makers using its coal, instead of imports, mostly from Russia and Poland. However, it plans to export about four-fifths of the coal to other parts of Europe and to Turkey. In the UK, steel-makers have raised concerns the coal may have sulphur levels too high for their needs.

UK steel-makers don't need to stick with coal, says Willis. "There are technologically available alternatives," she says, such as recycling steel using electric arc furnaces and adopting technology pioneered in Sweden to convert iron ore to steel using hydrogen instead of coal. However, Gareth Stace of trade body UK Steel says: "In the medium term, coking coal will remain an essential raw material for steel-making."

The mine has also resurrected an old debate pitting jobs against climate action. "I think the economic argument is a no-brainer," says Mike Starkie, mayor of Copeland Borough Council, which covers the area where the mine would be. WCM says it would create 532 jobs directly, which Starkie says would boost spending in the area. "It would be a tragedy if this mine doesn't go ahead," he says. Morris acknowledges the area needs jobs, but questions how long-term they will be and argues green projects would yield more employment.

"Allowing a new coal mine to open in the UK would completely undermine our international credibility"

If the mine goes ahead, it could have global implications. UK prime minister Boris Johnson called for the world to "consign coal to history" after the IPCC report, and the UK government is said to want an agreement on a global coal phase-out at COP26. A government spokesperson declined to comment while the inquiry is ongoing.

"Allowing a new coal mine to open in the UK would completely undermine our international credibility and the fragile, complex COP26 negotiations," says Ed Miliband of the UK's opposition Labour party. "How can a government tell others around the world they should not dig new coal whilst planning to do so themselves?"

The mine's future is likely to be decided after COP26. Willis argues that whatever the result, it will be the wrong one for people locally. "If they get it, they'll have an uncertain number of jobs in an industry that is on its way out. If they don't get the mine, they've got nothing," she says. "It just underlines how essential it is to look at the transition to net zero at a local level." ■

CHRISTOPHER FURLONG/GETTY IMAGES

The possible site near Whitehaven of a new UK coal mine

Coronavirus

Is it better to boost?

Some countries are keener than others to give a third round of covid-19 shots

Clare Wilson

AS A growing body of data suggests that vaccine-induced protection from covid-19 declines over time, many nations are gearing up to roll out a booster programme. Israel has already begun, while the US, France and Germany have all announced plans to begin rolling out third doses. Some other countries, including the UK, are holding back, with results from a key trial of third shots expected imminently.

The Joint Committee on Vaccination and Immunisation, which advises UK health departments, has been mulling over booster shots for some time. In June, it issued interim advice that any potential booster scheme should be offered in two stages from September, starting with care home residents, front-line healthcare and social care workers, people aged over 70 and adults who are clinically extremely vulnerable or immunosuppressed. But this is largely yet to materialise: all that has been announced so far is a limited programme of third shots for people who have severely weakened immune systems.

MAYA ALLERUZZO/AP/SHUTTERSTOCK

A coronavirus vaccine dose being given in Jerusalem last month

40%

Estimated protection against infection six months after standard vaccination

91%

Estimated protection against severe disease six months after standard vaccination

90%

Estimated protection against infection after a third shot (All percentages based on Israeli data)

Declining protection

There has been speculation since early in the development of the coronavirus vaccines that booster doses would be needed, perhaps to combat newer variants. But time is also a factor. For many diseases, the strength of the immune response – stemming from either natural infections or vaccines – wanes over time periods ranging from months to years.

Several studies have shown that, as expected, antibody levels fall gradually in the months after coronavirus vaccination. Antibodies aren't the whole story, as the memory cells that make antibodies and other immune cells called T-cells can persist in various sites in the body, ready to spring into action if needed, but it is much harder to detect these in people via tests.

However, we can measure how well vaccines are working in practice at stopping people from getting ill. Studies of covid-19 vaccination have given varying estimates of this. Recent Israeli data caused concern when it showed a person's protection from infection could be as low as 40 per cent roughly six months after the nation's vaccination programme began, although protection against severe disease seemed to be holding up, at 91 per cent.

Last month, a UK study also indicated that protection against symptomatic disease is falling quite rapidly, from 93 per cent two weeks after a second Pfizer/BioNTech dose to 71 per cent three months later. After two Oxford/AstraZeneca jabs, the figures were 72 and 61 per cent respectively.

Findings such as these are why some countries have begun offering third doses. In July, Israel became the first country to start providing boosters, to those aged 60 and over who had their second shot five months ago or earlier. Last week, this was extended to all adults and teenagers.

> "If it becomes a fact that we need three doses, then vaccine equality is going to suffer"

Results from the first people in Israel to get boosters show these work well at preventing both severe disease and milder infections. From 12 days after the third dose, the number of infections fell at least fivefold compared with people who'd had two jabs. "Our findings give clear indications of the effectiveness of a booster dose even against the delta variant," said Yair Goldberg at the Technion-Israel Institute of Technology in the study's online report.

Critics say the UK is an outlier for not having a booster programme in place by now. The UK government says the third shots now on offer to people with weak immune systems are technically not boosters, but "top-up" doses, to remedy the fact that two jabs don't seem to work fully in these people.

But the UK isn't alone: Spain, Denmark and the Netherlands have taken a similar stance. The European Centre for Disease Prevention and Control recently concluded that there is "no urgent need for the administration of booster doses in the general population".

Offering boosters so soon after the first two jabs raises the question of how often they will be needed, says Charlotte Thålin at the Karolinska Institute in Sweden. "We need to consider the effects of repeated immunisations – what side effects will that have? We haven't studied having third, fourth, fifth doses yet."

Global disparities

Another argument against boosting is that it is unfair to low-income countries, many of which haven't yet been able to give a first dose to most of their vulnerable groups. It is like giving extra life jackets to people already wearing them while others drown, said Michael Ryan at the World Health Organization last month.

"If we had a limitless supply of vaccines, I would say do it, but we don't," says Stephen Griffin at the University of Leeds, UK. "If it becomes a fact that we need three doses, then vaccine equality is going to suffer."

When *New Scientist* went to press, results were expected imminently from a key trial called Cov-Boost, which is comparing the effectiveness of seven different covid-19 vaccines when administered as third shots.

This will provide more information about whether it is advisable to "mix and match" the vaccine brands, which could provoke a stronger immune response based on past experience with other diseases. The UK programme offering a third vaccine to people with very weak immune systems will see the Pfizer/BioNTech or Moderna shots given to many people who previously had Oxford/AstraZeneca jabs. Israel, however, has been offering a third dose of the Pfizer/BioNTech vaccine to people who have already had two, and the US looks set to do the same. ▮

US healthcare

Texas abortion ban begins

A law that allows citizens to sue people "aiding and abetting" abortions in Texas could be copied by other states, says **Sara Novak**

ONE of the most extreme abortion laws in the US went into effect on 1 September in the state of Texas. The law bans abortion once cardiac activity in the embryo can be detected via ultrasound. This usually occurs around six weeks into a pregnancy, before many people even realise they are pregnant.

The law, known as Texas Senate Bill 8 (SB 8), doesn't have exemptions for pregnancies resulting from rape or incest, though it does have one for "medical emergencies".

While similar laws have previously passed in Georgia, Alabama, Ohio, Mississippi, Kentucky and South Carolina, they have been quickly struck down by state supreme courts and the US Supreme Court. Texas is the first state in which such a strict abortion law has become enforceable.

The difference is in how SB 8 is written. In every other state, people could sue state officials for enforcing an unconstitutional law – that is, laws that directly challenge the federal protection under the Roe v Wade ruling, which allows abortion up to 24 weeks "without excessive government restriction".

But SB 8 was written to avoid such a legal challenge. Under it, Texas citizens are charged with enforcement, not state officials, and allowed under the law to sue any individual for "aiding and abetting" someone seeking an abortion once cardiac activity is detectable, typically past the six-week mark.

As part of the legislation, doctors and clinic staff, as well as those driving someone to an appointment or helping pay for the procedure, are liable. Private citizens with no connection to the person getting an abortion can sue and recover damages of $10,000 plus legal fees.

"This cruel and dangerous law is among the most extreme in the entire nation," says Bhavik Kumar at Planned Parenthood Center for Choice in Houston, Texas.

According to Pew Research Center, 61 per cent of people in the US think abortion should be legal and 38 per cent think it should be illegal. The US Supreme Court had a chance to block SB 8 before it went into effect but didn't, in a 5-4 decision. Legal challenges to the law are under way, but this type of legislation could be passed in other states.

"The Supreme Court's failure to block Texas's draconian ban on abortion is already having a ripple effect in other states with legislatures controlled by anti-choice law-makers. In just a few short days, we have seen the anti-choice movement and anti-choice law-makers rush to export Texas's SB 8 to other states across the country," says Kristin Ford at abortion rights organisation NARAL Pro-Choice America.

"So far, we've seen law-makers in six states – Florida, Arkansas, Indiana, Mississippi, North Dakota and South Dakota – announce that they are considering or planning to attempt to ban abortion using copycat legislation," says Ford.

SB 8 makes getting an abortion in Texas an almost insurmountable obstacle for most people. Many aren't even aware they have missed a period and will never have an opportunity to consider their options, says Kumar. Teenage girls often don't realise they are pregnant until past the six-week mark. The poorest people may be most affected because those who fall below the US federal poverty level are two to three times more likely to have an unintended pregnancy.

"My patients deserve better. They deserve to make their own healthcare decisions in consultation with their provider, without political interference, and without the threat of frivolous lawsuits. Instead, the people of Texas are being robbed of their bodily autonomy and politicians are jeopardising the health and safety of pregnant people," says Kumar. ▮

ABORTION IS HEALTHCARE
GIRLS JUST WANNA HAVE FUNDAMENTAL HUMAN RIGHTS

Pro-choice protesters march outside the Texas State Capitol on 1 September

SERGIO FLORES FOR THE WASHINGTON POST VIA GETTY IMAGES

Analysis Space weapons

Saying no to space wars

A proposed ban on testing anti-satellite weapons would be a small step towards solving space junk, says **Jonathan O'Callaghan**

TODAY there are an estimated 27,000 pieces of trackable space junk in Earth's orbit, which includes anything larger than a tennis ball. The largest group contains pieces of exploded rockets left to drift around our planet. In close second are more than 3000 pieces of debris left over from anti-satellite tests. Now, a group of experts is calling for a ban on such tests, to stop the problem before it has disastrous consequences.

The use of weapons in space has been ever-present, and often shrouded in secrecy, in our short history of space flight. Anti-satellite tests have been more brazenly conducted, however. Both the US and Soviet Union used missiles on several occasions to practise destroying their own satellites in the 20th century, in anticipation of a conflict in space. Hundreds of pieces of dangerous debris remain from these tests, but they are eclipsed by China's infamous destruction of its Fengyun weather satellite in 2007. There are still 2865 pieces of debris from that event orbiting Earth.

"It remains… the single biggest contributor to orbital debris," says Jonathan McDowell at the Harvard-Smithsonian Center for Astrophysics in Massachusetts.

In a letter to the UN, experts from the Outer Space Institute – including former heads of state, astronauts and industry experts – are calling for a ban on such tests.

They say anti-satellite tests pose a greater danger than ever given the significant orbital debris risks due to the rising number of satellites in orbit, particularly from mega constellations such as SpaceX's Starlink and the UK's OneWeb.

27,000

Estimated pieces of trackable space junk in Earth orbit

"The mega constellations, with tens of thousands of satellites going into orbit, change the risk profile dramatically," says Michael Byers at the University of British Columbia in Canada, the letter's lead signatory. "[Banning anti-satellite tests] is no longer something that can be postponed."

A collision with even a small piece of space junk is enough to destroy a satellite, creating more debris. In turn, this could lead to rapidly rising levels of debris as more subsequent collisions take place, a cascade known as the Kessler syndrome. In a worst-case scenario, parts of Earth's orbit could be rendered unusable because of space debris. This could affect everything from Earth-imaging satellites involved in global food production to climate satellites that enable rapid responses to major disasters.

The letter comes as the US military is rumoured to be on the cusp of announcing a new space weapon, with speculation ranging from a kinetic anti-satellite vehicle to an electronic interference system. "If we get into a live-fire, open-conflict situation, we're going to accelerate the debris population very, very quickly," says Daniel Porras at US think tank Secure World Foundation, who is a member of the UN Institute for Disarmament Research.

Efforts to halt anti-satellite tests could take years. "The US has always shut down these considerations," says Victoria Samson, also at the Secure World Foundation.

Attempts to conduct anti-satellite tests responsibly have had mixed results. In 2019, India destroyed a satellite at lower altitude than previous tests, hoping the debris would re-enter the atmosphere within 45 days, but dozens of pieces remained after. "There's one piece still in orbit," says McDowell.

Neither China, the US nor Russia have conducted such a test in the past decade, but the danger remains. With the number of satellites in orbit set to increase 10 or even 100 times in the coming years, we must champion a sustainable use of space. Banning anti-satellite tests is the least we could do, says McDowell.

"It's a no-brainer," he says. "Deliberately creating space debris is just egregious." ▮

An artist's impression of space junk in orbit above Earth

FRAME STOCK FOOTAGE/SHUTTERSTOCK

Human biology

Diets rich in plants lead to excess emissions in men

Alice Klein

PLANT-BASED diets cause men to fart more and have larger stools, but that seems to be a good thing, because it means these foods are promoting healthy gut bacteria.

Anecdotally, it is well-known that eating more plants – including fruit, vegetables, grains and legumes – creates bulkier stools and increases flatulence. Claudia Barber at the Liver and Digestive Diseases Networking Biomedical Research Centre in Barcelona, Spain, and her colleagues compared the effects of a Mediterranean-style diet mostly comprised of plants with a Western-style diet containing fewer fruit and vegetables on the guts of 18 healthy men aged between 18 and 38. Each participant was randomly assigned to follow one of the diets for two weeks, then after a break, they switched to the other diet for two weeks.

The men did a similar number of poos per day on the two diets, but each one was about double the size on the plant diet. The men produced about 200 grams per day on the plant diet, compared with 100 grams on the Western diet. They also farted more frequently and produced more gas on the plant diet (*Nutrients*, doi.org/gt89).

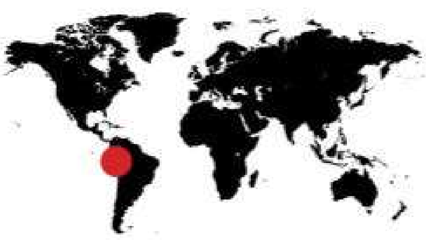
Both increases are down to certain types of gut bacteria that feed by fermenting plant fibre, says Rosemary Stanton at the University of New South Wales in Australia. The added stool weight is made up of the spent bodies of these extra bacteria plus water and some undigested plant fibre, she says.

These fibre-fermenting bacteria are known as "good" bacteria because they release short-chain fatty acids. These chemicals keep the large intestine healthy and protect against bowel cancer. Short-chain fatty acids can also be absorbed into the bloodstream where they protect against heart disease and diabetes. ▮

Botany

Fog oases surveyed

Peru and Chile have fog-fuelled ecosystems, but they are threatened



Krista Charles

DOTTED along the arid coasts of Peru and Chile are green spaces called fog oases (pictured) that provide clean air, water and medicinal plants to local communities. Now they have been mapped by scientists for the first time.

Plants within the oases capture water from fog rolling onto the land from the sea. This means they react quickly to changes in sea temperature, leaving them threatened by climate change.

Justin Moat at Royal Botanic Gardens, Kew, in the UK and his colleagues have used satellite data to show that the oases, which are ephemeral, can exist across 17,000 square kilometres – an area four times greater than previously thought (*International Journal of Applied Earth Observations and Geoinformation*, doi.org/gvcz).

"The local people living there know about them, but it gives us that knowledge," says Moat.

HUDSON YONJOY

Medicine

Mixing drugs could slow antibiotic resistance

ANTIBIOTIC resistance is one of the biggest threats to public health, yet a surprisingly simple tactic could help tackle it: alternating between three different antibiotic medicines.

The approach has so far only been tested on bacteria grown in a dish, but employing this method with commonly used antibiotics killed bacteria five times more efficiently than using one drug at a time.

If trials in people give similar results, it could be used to combat antibiotic resistance by asking people to take a different drug out of three every day, says Hinrich Schulenburg at the University of Kiel in Germany.

Antibiotics are seen as one of the greatest developments of modern medicine, transforming potential killers like wound infections and tuberculosis into something treatable with a course of tablets. But the potency of these medicines is waning because bacteria can mutate to become resistant to their effects, and new drugs aren't being developed fast enough. There are global campaigns to try to preserve our remaining antibiotics by reducing our use of them.

Doctors already change to a different antibiotic if the bacteria causing an infection become resistant to the first drug used, typically after a few weeks. Schulenburg and his colleagues wondered whether a strategy of rapid switching from the outset would be helpful.

In 2018, the team showed that if bacteria in a dish are treated by rapidly switching between three antibiotics that work through different mechanisms, the microbes take longer to develop resistance than if the medicines are cycled more slowly over a few weeks. The experiment used levels of antibiotics that were lower than normally given to people, in order to encourage resistance to develop.

"Bacteria treated by rapidly switching between three antibiotics take longer to develop resistance"

In the latest study, the researchers found that the rapid-cycling approach was even more potent if they used three closely related antibiotics from a class called beta-lactams. These are often used to treat *Pseudomonas aeruginosa* bacteria, which can cause wound infections and pneumonia (*eLife*, doi.org/gt79).

Sticking with three antibiotics from the same class means it is less likely that one of them will trigger allergies or side effects, says Schulenburg. If the approach translates well to people, "we could use available antibiotics in a more effective way", he says.

Clare Wilson

Biodiversity

Fires crowd endangered species

Most endangered species in the Amazon had their range cut by blazes

Adam Vaughan

ALMOST all the endangered species in the Amazon rainforest have seen their habitats negatively affected by fires over the past two decades, researchers have found.

Home to a tenth of the world's known species and around 40 per cent of the planet's remaining tropical forests, the Amazon ecosystem hasn't evolved to cope with the fires that are often set within the rainforest to clear land for cattle farming.

A team led by Xiao Feng at Florida State University says the region appears to have entered a new phase in 2019, when Amazon fires skyrocketed following a relaxation of deforestation enforcement encouraged by Brazilian president Jair Bolsonaro. While fires in recent years have been closely studied, their impact on biodiversity hasn't been as well-documented.

To address the gap, Feng and colleagues combined satellite data of forest fires between 2001 and 2019 with maps of the ranges of more than 3000 species of mammals, birds, reptiles and amphibians, plus modelling to estimate the distribution of more than 11,000 plant species.

Up to 85 per cent of the region's species that are already on the IUCN Red List of threatened species, such as the endangered white-cheeked spider monkey, were found to have had between 5 and 15 per cent of their geographic range affected by fires, such as by a loss of habitat or fires directly killing individuals (*Nature*, doi.org/gmn9b3).

"Most of the species have been somehow impacted either to a small degree or a large degree," says Feng. While most of the total 14,000-plus species only had a small encroachment on their ranges, the biggest impact was on endangered species and those only found in a few places, such as *Remijia*, a group of flowering plants.

The research also reveals how closely the impacts on biodiversity followed Brazilian government policy. The effect was greater during rampant deforestation before 2009, and disappeared almost completely between 2009 and 2018 in the face of Brazil's anti-logging measures. It then picked up again in 2019 during the relaxation in enforcement under Bolsonaro, in what the team says was one of the "most extreme" years for biodiversity impacts from fires since 2009.

A Brazilian firefighter holding a dead anteater after a fire in the Amazon

UESLEI MARCELINO/REUTERS/ALAMY

The research comes with some caveats. The study doesn't cover all the Amazon's plants – it is missing about 14 per cent of verified species in the region – and the satellite data for the fires is likely to be an underestimate because clouds hid some blazes.

"These new estimates are still likely to be very conservative given the patchy nature of the distribution of many Amazonian species, which is not captured by existing range maps," says Alexander Lees at Manchester Metropolitan University in the UK.

Even if the amount of forest being burned stays steady in years to come, the Amazon could see worse impacts on biodiversity if fires burn the inner parts of the region, because the heart of the rainforest has a greater richness of species. "In terms of the future, I'm not that optimistic. We are not allowing the forest to recover," says Feng.

Technology

Call centre workers can mimic your accent with AI

AI SOFTWARE can detect the accent of a person on one end of an online or telephone conversation and modify the accent of a person responding to match it in real time.

US-based start-up Sanas hopes its technology will enable greater understanding and clarity in a range of interactions, including customer support, education and telemedicine. The company says that audio can be manipulated to match an accent with a delay of just 200 milliseconds.

The software intercepts sounds between the microphone and whichever software is being used to communicate, whether that is Zoom, Microsoft Teams or Skype, and alters what is broadcast. It converts accents using a neural network that has been trained on a range of audio clips, including files found online, recordings made of strangers on the street in cities around the world and recordings made by call centre staff.

Andrés Pérez Soderi at Sanas says that some elements of the AI system are a "black box" and that the way it alters voices isn't known. He says the team quickly realised during development that the AI couldn't be designed to transcribe speech to text and then generate an artificial voice to read it in a new accent, as errors in transcription would occur and there would be a lag in computation that rendered it useless for conversation. The team eventually settled on a model that is based on individual phonemes – the distinct sounds that make up words – and therefore was able to begin changing the stream of audio before each word was finished.

"The software converts accents using a neural network trained on a range of audio clips"

Pérez Soderi says that Sanas is in talks with businesses to roll out the technology in coming months.

Matthew Sparkes

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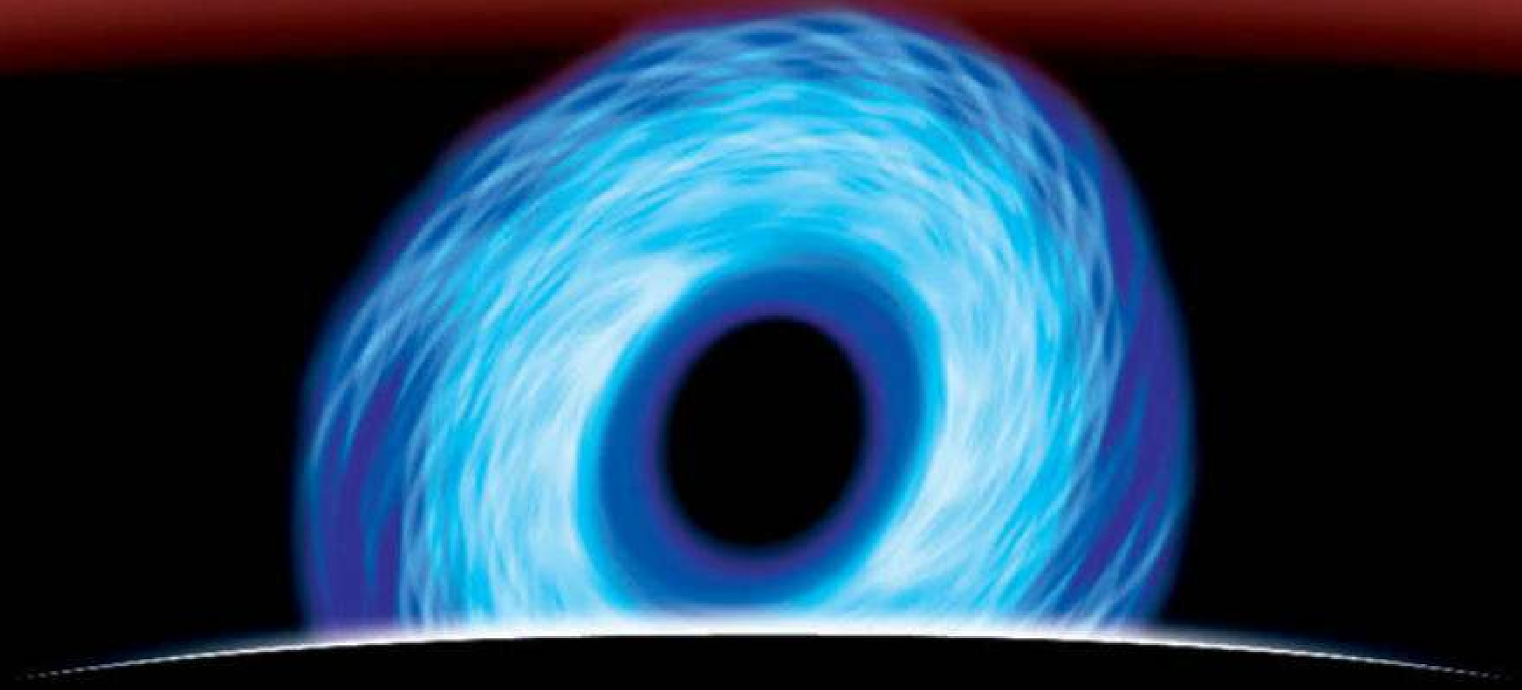

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Ecology

Zebras give life to the Namib desert by rolling around

Richard Kemeny

ROLLING on the ground seems to be essential to life – at least in Africa's Namib desert, where zebras bathe in dust, creating pits that promote biodiversity.

The Namib desert is a vast stretch of dunes and mountains along the coasts of Angola, Namibia and South Africa. It is the world's oldest desert and one of the driest.

Despite this extreme aridity, many animals and plants have adapted to survive, including the Hartmann's mountain zebra (*Equus zebra hartmannae*). Herds live on the mountainous desert edge, migrating with rainfall. The zebras often roll in the dusty ground to groom and get rid of parasites. As part of this process, they hoof out large stones and displace the soil, making comfortable spots in which they rest and leave dung.

These pits can reach up to 30 centimetres deep and can last for years. Thomas Wagner at the Technical University of Munich, Germany, wondered if there were ecological benefits to this accidental landscaping. Over five consecutive rainy seasons, Wagner and his team calculated vegetation cover from drone images in more than 650 rolling pits, tracking the greening and wilting of the landscape following rains. They sampled soil and plants in 16 of the pits, using surrounding grassland as controls.

The researchers found that rolling pits were mostly composed of finer soil and sand, instead of gravel. This allows rainwater to filter into the soil roughly twice as deeply as in nearby grassland, collecting like a pond and keeping the soil moist for longer. Levels of nitrogen and phosphates were higher too, probably because of the dung. The rolling pits were greener for longer, and were dominated by forbs – flowering plants – in place of perennial grasses (*Ecology and Evolution*, doi.org/gt8k). ▮

Analysis **Transportation**

Green shipping hoves into view

Maersk, the world's biggest shipping company, is investing in an alternative to oil, but the transition won't be easy, finds **Adam Vaughan**

SHIPPING is a bigger contributor to climate change than aviation, and remains one of the few sectors where emissions are growing instead of falling. It has yet to find a sure-fire way to decarbonise. Last month might mark a turning point. On 24 August, Maersk, the world's biggest shipping company, said it had ordered eight ships capable of running on both normal oil-based fuel and a type of alcohol, methanol.

These won't be the first ships running on methanol – there are about 20 globally already – but they will be by far the biggest: cargo ships capable of holding 16,000 containers. Importantly, Maersk has promised to not just have the shipping equivalent of a "4K-ready" TV, but to run them on methanol rather than oil "as soon as possible".

The Danish shipping company has paid careful attention to detail on how the methanol will be made. "I was pleasantly surprised. It's an impressive pace and scale," says Bryan Comer at the International Council on Clean Transportation, a US non-profit organisation.

So why methanol, and what impact could it have if it is more widely adopted in shipping? When burned, it emits less carbon dioxide into the atmosphere than fuel made from oil, and that CO_2 can theoretically be cancelled out by the way the methanol is made. It also hugely cuts air pollutants.

Maersk disregarded generating methanol using fossil fuels – a method that can be even more polluting than today's shipping fuels. Instead, it is looking at two methods for producing methanol. The first is "e-methanol" using green hydrogen and CO_2 removed from the air or a power plant. The second is "biomethanol" made from biomass, such as waste from landfill, crops or trees. Morten Bo Christiansen at Maersk sees biomethanol leading the way initially because it is cheaper, being eclipsed in 10 to 15 years' time by e-methanol because it can reach larger scale.

400,000

tonnes of methanol will be needed for the new ships

Making enough of either cheaply will be hard. Both cost more than conventional fuel. Even in a best-case scenario, biomethanol is twice as expensive as fossil fuels, says Christiansen. Less than 200,000 tonnes of biomethanol and e-methanol are currently produced annually. Maersk thinks it will need between 300,000 and 400,000 tonnes annually for its eight ships, which are due for delivery in 2024.

Comer illustrates the scale of the longer-term challenge. He estimates that the whole Maersk fleet would require between about 20 and 24 million tonnes of methanol, which is about half as energy dense as today's fuel. The world makes 90 million tonnes of methanol annually at the moment, almost all of it from fossil fuel.

A leading alternative clean maritime fuel is "green ammonia", which is cheaper and easier to make, says Delphine Gozillion at non-profit organisation Transport & Environment in Brussels, Belgium.

Christiansen explains why Maersk chose methanol instead: "If you look at the matureness of the technologies, and not least the operational and safety aspects, that is where methanol is a far, far better fuel." Ammonia is more toxic and, as a gas rather than liquid, is harder to handle.

Unfortunately, Maersk remains a rare example of a company in the shipping industry looking to leapfrog "better" fossil fuels for genuinely low-carbon fuels. Its French and German rivals are mainly pursuing liquefied natural gas (LNG) instead, encouraged partly by UN and EU regulations. Yet methane leaks from LNG engines and gas wells mean the fuel can have an even greater climate impact than oil in some cases. ▮

The Murcia Maersk container ship runs on conventional fuel

JONATHAN NACKSTRAND/AFP VIA GETTY IMAGES

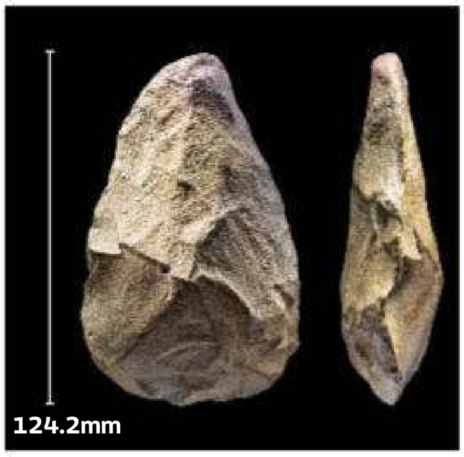
Human evolution

Five times into Arabia

Ancient humans repeatedly entered the peninsula during the past 400,000 years

Michael Marshall

CERI SHIPTON



INSTITUTE OF ARCHAEOLOGY OXFORD UNIVERSITY

Top: northern Saudi Arabia was inhabited in times of higher rainfall
Left: a stone hand-axe tool from -Khall Amayshan-4

400,000

years since an Arabian site was first occupied by early humans

A SINGLE archaeological site in Saudi Arabia holds evidence of five separate occupations by ancient humans. Together with new prehistoric climate simulations of the region, the study sheds more light on the Arabian peninsula's role in human history.

Huw Groucutt at the Max Planck Institute for Chemical Ecology in Jena, Germany, and his colleagues excavated a site called Khall Amayshan-4 in the Nefud desert in what is now northern Saudi Arabia. In a single hollow between sand dunes, the team found the preserved remains of several lakes that had formed during spells of wetter climate and then dried up (*Nature*, doi.org/gtzd). "This was a really exceptional site," says team member Paul Breeze at King's College London.

The lakes at Khall Amayshan-4 existed about 400,000, 300,000, 200,000, 130,000 to 75,000 and 55,000 years ago. In each case, the team found stone artefacts left by hominins. But no two assemblages were the same. The oldest two contained mostly hand-axes (pictured), but of different designs. The three more recent ones featured stone flake tools, which are evidence of fairly complicated tool manufacture, but again the designs were significantly different. The team argues that each group of artefacts represents a separate migration into the area, by a different group, and perhaps different species.

The most recent occupation, about 55,000 years ago, is around the time our species (*Homo sapiens*) expanded out of Africa into Europe and Asia, and on to Australia. This happened between 80,000 and 40,000 years ago, says team member Eleanor Scerri at the Max Planck Institute for the Science of Human History, also in Jena. The people at Khall Amayshan-4 some 55,000 years ago may have been part of that diaspora, she says.

It isn't certain who any of the occupants were, though, because no hominin bones were found. The occupation 400,000 years ago was before *H. sapiens* evolved. Some assemblages may represent African hominins moving into the Arabian peninsula, but some of the artefacts look Neanderthal, suggesting Neanderthals came in from Eurasia, says Groucutt.

The temporary lakes formed when the Arabian climate temporarily became wetter, so rivers flowed between the sand dunes and lush vegetation grew.

In a second study, a team led by Andrea Manica at the University of Cambridge simulated the climate of the Arabian peninsula and north-east Africa over the past 300,000 years, to figure out when conditions were best for hominins to migrate from Africa to Asia.

The team created maps of rainfall during different periods and looked for times when continuous corridors of rainy climates existed, which early humans could have expanded through. The simulations identified several windows when the climate was suitable for human populations to expand from Africa into Asia (*Nature Communications*, doi.org/gtzf).

The windows largely matched the occupations found at Khall Amayshan-4. "Their episodes line up remarkably well with ours," says Manica. For instance, the Nile and Sinai regions were liveable between 246,000 and 200,000 years ago – in line with an Arabian peninsula occupation about 200,000 years ago. This area reopened between 130,000 and 96,000 years ago, potentially explaining the occupation 130,000 to 75,000 years ago.

The Arabian peninsula was only intermittently inhabited, says Scerri. That may mean it was a boundary where different hominin groups could sometimes meet. For Groucutt, this suggests that early humans and Neanderthals may have interbred in Arabia. Today, everyone whose ancestry is mostly non-African carries some Neanderthal DNA. This hints that the two groups met shortly after the out-of-Africa expansion began. Exactly where is uncertain. Thanks to Khall Amayshan-4, says Groucutt, Arabia is now a place where we have Neanderthal-style tools and human-style tools very close in time, which suggests that the groups may have overlapped.

The two studies also have implications for the route hominins took when moving from Africa to Asia. The two main possibilities are a northern route through the Nile and Sinai, and a southern route across the Bab-el-Mandeb strait: the narrowest point of the Red Sea between Africa and the Arabian peninsula. For Groucutt, finding multiple occupations in north-west Arabia "quite strongly supports the northern route". But Manica argues that both routes may have been used at different times.

For Manica, the baffling thing is why it took so long for *H. sapiens* to successfully expand out of Africa, when the climate repeatedly enabled it. The earlier wet spells were actually better than the one about 60,000 years ago. "They came out at a period that was OK but not the ideal period," he says. ■

Technology

Large Hadron Collider sticks with reels of tape for vast data storage needs

Matthew Sparkes

THE Large Hadron Collider (LHC), which wakes from a three-year shutdown next month when beam tests begin ahead of cutting edge experimental work, is still archiving its data using a distinctly old technology: magnetic tape.

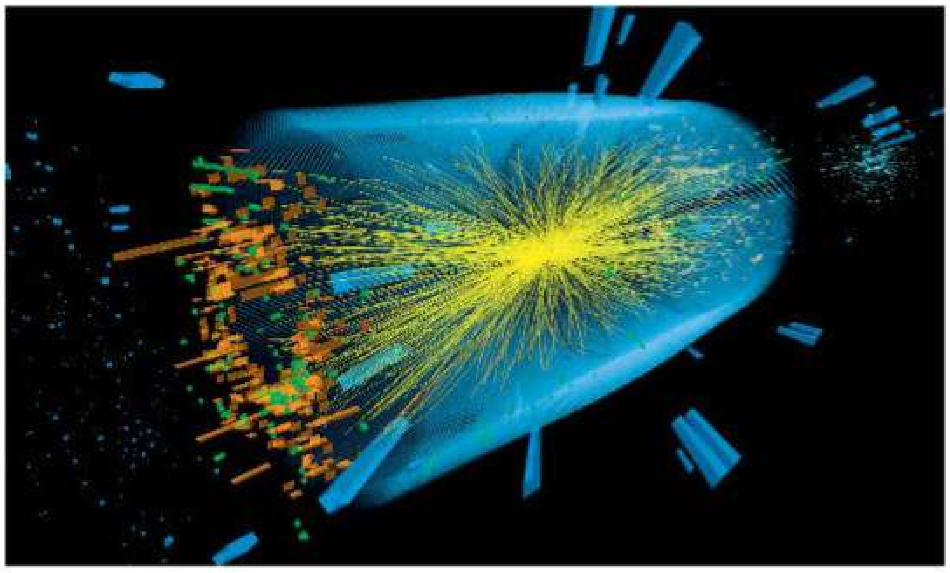
During its downtime, upgrades were made to the computer centres that handle the vast amounts of data produced when particles smash into each other close to the speed of light. But, despite the LHC being the most expensive scientific instrument built, the information it collects is still stored on a medium pretty much unchanged since 1952.

Alberto Pace at the CERN particle physics laboratory near Geneva, Switzerland, which hosts the LHC, says that when it comes to storage "we are looking for cheap", and on that, tape trumps hard discs or flash memory.

This isn't to say that CERN avoids using hard discs altogether. In fact, the Large Hadron Collider data centre contains around 90,000 of them, with a combined capacity of 487 petabytes – which is enough to store 974,000 years of MP3 music. But they are only used for short-term analysis: the content is stored in duplicate on hard discs for no more than a few months and is then deleted to make way for more information gathered at the collider.

Before the hard discs are wiped clean, the content is copied onto tape storage for permanent backup, and duplicated in data centres around the world.

Particle collisions inside the LHC generate lots of data



MCCAULEY, THOMAS/CERN

Tape carries many advantages, says Andy Walls at IBM, which invented tape storage in 1952 and which supplies storage hardware to CERN. If stored carefully, tape can last for decades. This makes it more reliable than hard discs, 30 of which fail each week at the LHC. It also consumes no power while sitting idle.

If necessary, data stored on tape can later be moved back onto hard discs for use in a fresh analysis. "Sometimes [the physicists] see something interesting in their analysis," says Pace. "So they want to rewrite the software and recall the data from tape."

There are still costs associated with tape storage at this scale. CERN has 50,000 tape cartridges for permanent backups, and requires robots to physically insert, remove and file tape cartridges as needed. The physics lab must also use specialist software to manage the data stored on tape. Hard discs or flash storage would remove the need for these overheads – but would still not come close to beating tape on cost overall.

Walls says 1990 was the first time someone told him tape storage was dead. Nonetheless, he says it remains the best option for large operations.

"If you have to deal with tens of petabytes, exabytes of data, and you need to do so inexpensively, economically, tape is a way to go – especially if what you're doing is kind of a sequential throughput where you're bringing in lots of data at one time," says Walls. "I don't see anything on the horizon that's going to overtake or eliminate it." ▮

Climate change

Texas cold crisis linked to melting Arctic sea ice

AN EXTREME cold snap that left millions of people in Texas without power last winter appears to have been made more likely by melting Arctic sea ice, research suggests.

For the past decade, evidence has been building in support of the counter-intuitive idea that some of the recent cold winter spells at mid-latitudes in North America and Eurasia are linked to the Arctic warming faster than the rest of the world due to climate change.

That link still isn't fully established. However, a group led by Judah Cohen at the Massachusetts Institute of Technology found that vanishing sea ice and greater snowfall in the Arctic over the past 40 years – effects caused by climate change – may be driving cold winter weather in North America and Eurasia via the stratospheric polar vortex, the cold winds high above the pole.

The rapid warming in the Arctic appears to be stretching this vortex in a way that has a knock-on effect on atmospheric circulations above North America, generating unusually cold spells in winter.

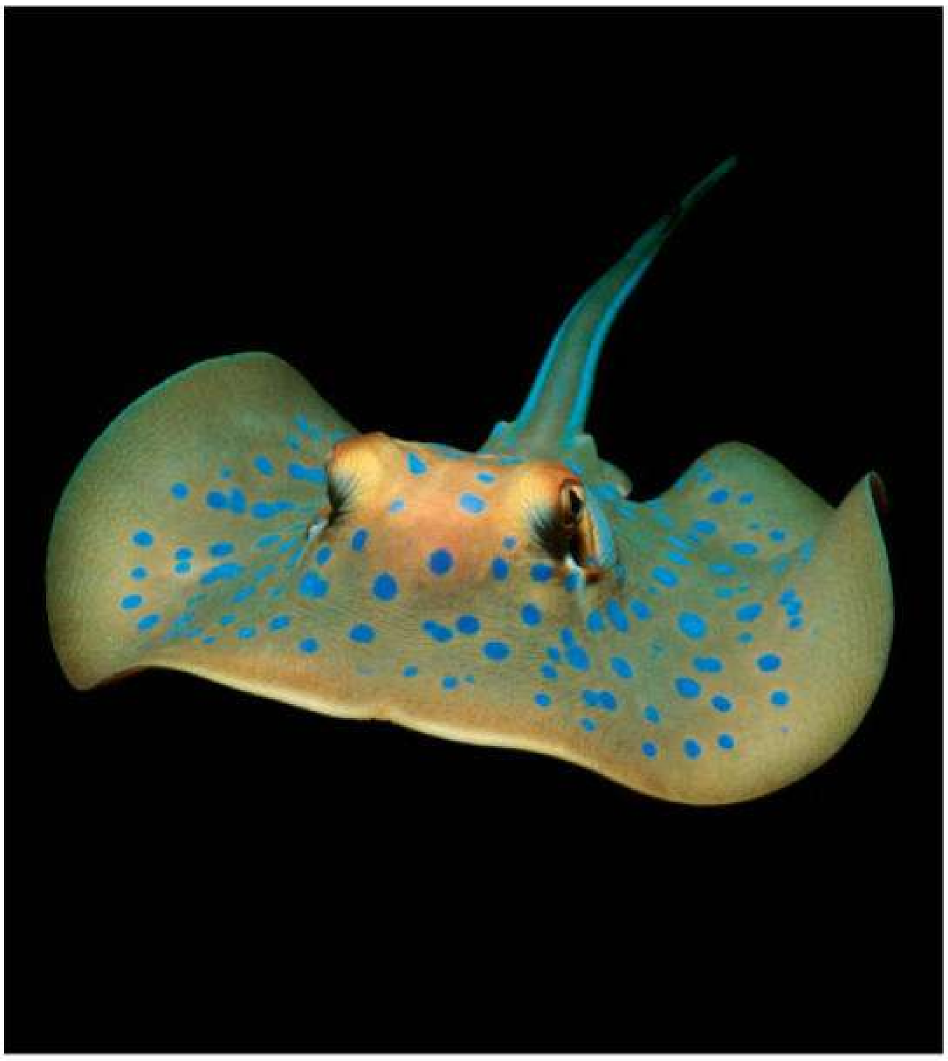
"This is an unexpected impact from climate change that we didn't appreciate 20 years ago," says Cohen (*Science*, doi.org/gtxk).

The researchers arrived at their findings using modelling of Arctic snow and sea ice, as well as observations of snow and sea ice from October 1980 to February 2021. They also used data on the polar vortex and temperature data for North America. Cohen and his colleagues say their analysis suggests that the cold that hit Texas in February was probably a response to disruption in the stratospheric polar vortex in the same month.

> "This is an unexpected impact of climate change that we didn't appreciate 20 years ago"

Jennifer Francis at Woodwell Climate Research Center in Falmouth, Massachusetts, says: "The conclusions are well supported and help explain how extreme cold spells like the debilitating one in Texas this past February are still likely as the climate crisis unfolds." ▮

Adam Vaughan



JEFF ROTMAN/ALAMY

Zoology

Bulging eyes help make rays champion swimmers

WITH their smooth, flexible fins, stingrays are very efficient swimmers – but their eyes and mouths stick out, which seems like it would create drag and slow them down. It turns out that these bulging faces have the opposite effect, allowing stingrays to swim even faster and more efficiently.

Hyung Jin Sung at the Korea Advanced Institute of Science and Technology in South Korea and his team examined how the protruding eyes and mouths of stingrays affect how they move through the water using a series of hydrodynamic simulations. Some of the simulated rays had eyes and mouths, some only had one or the other and some were completely smooth.

They found that the protrusions created a set of vortices as the water moved over them. One vortex pushed water towards the back of the ray, leaving an area of lower pressure in front of it. This low-pressure zone allowed the simulated rays to swim faster.

Another vortex sloshed water to the sides, increasing the pressure below the ray and decreasing the pressure above it. This made each stroke of the fins generate more thrust, increasing the efficiency of swimming.

Sung says he was "very surprised" at the results, particularly by the magnitude of the effect – the analysis showed that stingrays' eye protrusions increased their propulsion efficiency compared with rays without these features by about 20.5 per cent, and their mouth increased it by about 10.6 per cent (*Physics of Fluids*, doi.org/gtwn). **Leah Crane**

Animal behaviour

Who's a clever boy? Parrots carve tools

SOME wild cockatoos whittle tree branches into utensils to open and dig into the seed-laden pits, or stones, of tropical fruit.

This is the first known instance of wild, non-primate animals making and using tool sets, say Mark O'Hara and Berenika Mioduszewska at the University of Veterinary Medicine, Vienna.

O'Hara, Mioduszewska and their colleagues regularly study wild Goffin's cockatoos (*Cacatua goffiniana*) in Indonesia. They occasionally capture the small, white parrots and keep them in an outdoor aviary to observe their behaviour before releasing them.

In the Indonesian islands, Goffin's cockatoos are the only known species to eat sea mangos, a small, tropical fruit toxic to humans. The researchers offered the hard-pitted fruit to 15 of these birds in their aviary. Two of the larger and apparently older males grabbed a sea mango and flew into a tree to strip wood from the branches with their beaks. Using their tongues and beaks, the parrots crafted wood slivers into usable tools of three different sizes and thicknesses, O'Hara says. Then, aiming with their beaks, they artfully jabbed their cutlery into the fruit's pit.

The researchers collected the discarded tools and created 3D models of them to better understand how they were made and the purposes they served. The thinnest tools were sharp like knives and let the birds pierce the pit's parchment-like coating, says O'Hara. Medium-sized tools worked like spoons, allowing the birds to dig into the pit and pull out nutritious seeds. Sometimes the cockatoos also used the thickest tool as a wedge, prying the pit apart, which made it easier to shove their knives and spoons inside (*Current Biology*, doi.org/gtdn). **Christa Lesté-Lasserre**

Environment

Illicit US marijuana farms kill wildlife

ILLEGAL cannabis farms on public land on the US west coast are killing threatened native species through pesticide poisoning.

Greta Wengert at the Integral Ecology Research Center in Blue Lake, California, first got an inkling of the scale of this problem when cat-sized, ferret-like mammals called fishers (*Pekania pennanti*) turned up dead after exposure to rodenticides. This was a surprise, as the animals' usual habitats are far from human developments.

BOGDAN KURYLO/ALAMY

Wengert and her team suspected that the rodenticide was coming from illegal cannabis farms, where it is often used to kill pests. To check this, the team used modelling to predict where illegal cannabis farms and three different threatened predators – fishers, Humboldt martens (*Martes caurina humboldtensis*) and northern spotted owls (*Strix occidentalis caurina*) – would be most likely to intersect.

Areas with a moderate-to-high likelihood of cannabis cultivation overlapped with more than 44 per cent of fisher habitat, and about 48 per cent of spotted owl and 40 per cent of Humboldt marten habitat, suggesting a high risk of pesticide exposure. A survey of some areas predicted to have a higher likelihood of hosting cannabis farms found 16 sites that were previously unknown, proving the model's predictive power (*PLOS One*, doi.org/gtwp). **Jake Buehler**

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Really brief

LIUDMILA BOHUSH/SHUTTERSTOCK

Dog breed has lots of genetic problems

By 11 years of age, nearly all cavalier King Charles spaniels have heart disease, and a DNA study may suggest why. The dogs carry more genetic mutations than eight other breeds, such as German shepherds. These include mutations to the heart-specific *NEBL* gene (*PLoS Genetics*, doi.org/gtws).

Nose cartilage can fix damaged knees

Implants made from nose cartilage have been used to repair the knee joints of two people in their 30s with severe osteoarthritis. The treatment may offer an alternative to the prosthetic joints offered to people with knee pain caused by cartilage damage (*Science Advances*, doi.org/gsqg).

Fast-evolving DNA linked to the brain

Some 210 snippets of DNA in the human genome that are known to have evolved rapidly since our species originated seem to play a role in brain development. In the lab, the DNA snippets enhanced the activity of genes in human neural cells, but it isn't yet clear how this affects the brain (*Neuron*, doi.org/gtw7).

Technology

Walking around your home could light it up

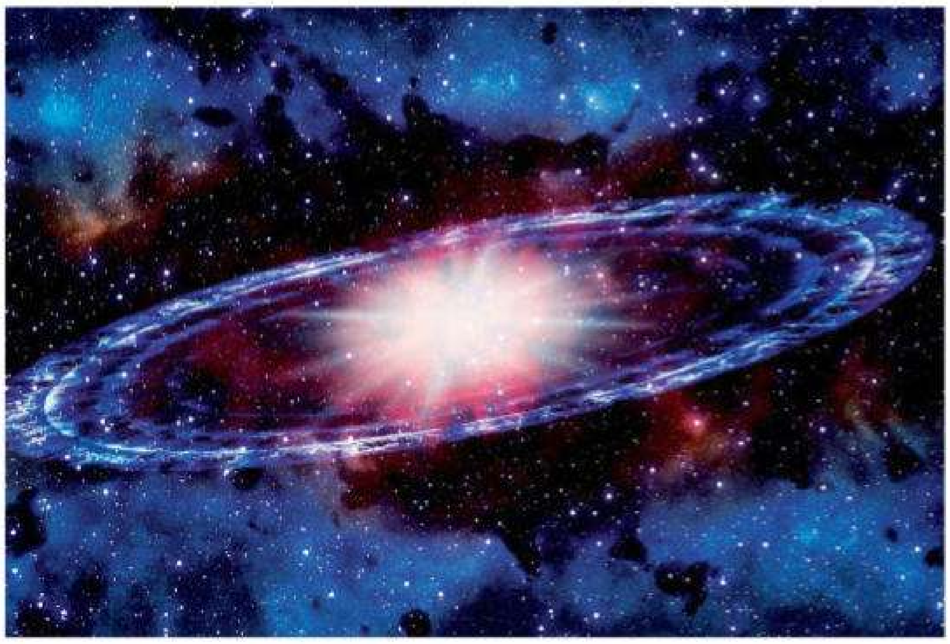
WOODEN floors that are infused with silicon and metal ions can generate enough electrical power from our footsteps to light LED bulbs. Researchers hope that this could provide a green energy source for homes.

Some materials can generate an electrical charge when they come into contact with another such material and are then separated, due to a phenomenon called the triboelectric effect. Electrons are transferred and generate a charge. The materials that tend to donate electrons in this process are known as tribopositive and those that tend to receive them are known as tribonegative.

Guido Panzarasa at ETH Zürich in Switzerland and his colleagues found that although wood sits in the middle of this spectrum and doesn't readily pass electrons, it can be altered to generate larger charges. The team infused one panel of wood with silicon, which picks up electrons on contact with an object. A second panel was infused with nanocrystals of zeolitic imidazolate framework-8, a compound that contains metal ions and organic molecules, and these crystals have a tendency to lose electrons.

The team found that this treatment rendered a surface that contained both wooden panels 80 times more efficient than standard wood at transferring electrons. This meant it was powerful enough to light LED bulbs when human footsteps compressed the material and brought the two types of panels into contact (*Matter*, doi.org/gtxj). **Matthew Sparkes**

Astrophysics


JVPHOTO/ALAMY

Strange star death spotted in a galaxy far, far away

ASTRONOMERS have found a new type of supernova in a galaxy about 500 million light years away from Earth. Unlike usual supernovae caused by a star's spontaneous collapse, this explosion – a merger-triggered core collapse supernova – was expected to occur where two stars orbit each other, but hadn't been seen before.

Dillon Dong at the California Institute of Technology in Pasadena and his team searched data from the Very Large Array Sky Survey in 2017 and 2018 for bright, radio-emitting objects. They found one blast of radiation that was far brighter than the rest. Follow-up observations and archival data revealed a blast of gamma rays that came from the same spot in 2014.

Combining all this information led the researchers to a clear picture of this object's history. Calculations indicate it was a massive star orbiting a more compact object, either a neutron star or a black hole, that over time fell into the star.

Eventually, the compact object disrupted the star's core, creating the powerful jet that was observed in 2014. At a slightly slower pace, the entire star exploded, causing the radio wave signal that first caught the attention of Dong and his team (*Science*, doi.org/gtw3). LC

Animal physiology

Twist in the tale of the scorpion sting

SCORPION tails can twist and bend at the same time thanks to unusual joints, which could inspire new kinds of robots.

A detailed analysis of this body part reveals that its joints move simultaneously in ways similar to both a door hinge and a rotating wheel, allowing highly precise sting strikes, while also allowing body tissues to run through its hollow structure.

Alice Günther at the University of Rostock in Germany and her team used computed tomography (CT) scans of the five tail segments of a laboratory-bred adult female *Mesobuthus gibbosus* scorpion to determine the structure. This species was chosen as it has a tail typical of most of these animals (*Journal of the Royal Society Interface*, doi.org/gtw9).

The tail's design could be of interest for industries that need to transport fluids through articulated arms, says Günther.

Doctors and surgeons could deliver targeted treatments into specific body parts through such devices, for example, or cables and other sensitive equipment could be protected inside jointed robots, says Fabrizio Scarpa at the University of Bristol, UK, who wasn't involved in the work. **CLL**

New Scientist Events

ONLINE EVENT

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JIM AL-KHALILI

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Comment

A toxic error

Heavy metal pollution limits shouldn't just keep humans safe, but other animals too, say **Coline Monchanin** and **Mathieu Lihoreau**

MICHELLE D'URBANO

ACROSS the world, insects are in decline. Intensive pesticide use, new diseases, habitat destruction and climate change are all contributing. Sadly, we are increasingly discovering that there is another impact of our everyday activities that is just as important: heavy metal pollution.

These substances are all around us. They are naturally present in Earth's crust and are released at low levels through weathering of rock and volcanic activity. But this gets a significant boost from human activity. We release these metals in various ways, ranging from dust that comes from vehicle brakes to the burning of fossil fuels for power and transport. All of this raises concentrations above natural levels. And once metallic dusts are out there, they stay for millennia.

While some of the compounds of these metals are essential for living organisms, most of them are highly toxic even at low concentrations. There are international guidelines designed to protect us from such pollution, but it turns out they aren't strong enough to do the same for insects.

In our recent work, we surveyed the scientific literature from the past 45 years that looked at the most monitored metals: arsenic, cadmium, mercury and lead. From this, we were able to identify the concentrations of these that are harmful to terrestrial invertebrates, the majority of which are insects. We then compared them with thresholds for the metals recommended by international regulatory bodies, for food, water and soil.

Though amounts of these in the environment should be below "human-safe" limits, in almost half of the studies the levels in natural conditions exceeded these figures. Not so surprisingly, at these concentrations the metals almost always killed invertebrates. More alarmingly, 90 per cent of the studies investigating metal levels within "human-safe" limits reported harmful effects on insects.

What's more, while it is clear that contamination harms these animals, we only have a partial picture as studies focus on sentinel species such as moths and bees, so-called because we use them to give an idea of possible harm to people, and on organisms favoured in many lab studies such as *Drosophila*. While we expect these to reflect a broad pattern, they only represent a tiny fraction of insect biodiversity, which is by far the most abundant of the terrestrial animals on the planet. A deeper understanding is critical to find the best possible solutions to mitigate these effects.

We need to start now, so we are calling for urgent action. While many local initiatives have worked to reduce emissions of some specific metal pollutants and emission sources over the past 40 years, environmental metallic pollution globally is still high. Take lead, for example, which started to be banned from petrol in the 1980s, but remains high in the environment because of the processing of ore and metals, and use of leaded aviation gasoline.

We could effectively reduce metal emissions now by dramatically cutting the use of fossil fuels, gasoline vehicles and metal-based pesticides, which are all sensible ways to protect our environments.

Politicians and scientists also have to rethink guidelines about what a safe level of metal pollution is, to take account of non-human species. This kind of shift in thinking was achieved a few years ago for broad scale use of harmful pesticides in intensive agriculture in many parts of the world.

Metal pollution is still an underappreciated threat. Its potential contribution to the huge insect biodiversity decline, called "insectageddon" by some, hasn't been recognised in recent conservation plans, such as the proposal for a more sustainable European Union Common Agricultural Policy. It is time for that to change. ▮

Coline Monchanin is at Paul Sabatier University, France. Mathieu Lihoreau is at Macquarie University in Sydney

#FactsMatter

When foods become taboos

There is an increasing number of people who think seedless fruits are bad for you, but actually the opposite is true, writes **James Wong**

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm reading

Lots of studies on soy and corn cultivation for a new documentary I am filming in the US Midwest on the future of farming.

What I'm watching

After a long wait, I am so excited about the new series of Grace and Frankie.

What I'm working on

Another season of Follow the Food, *which is a global documentary by the BBC on how civilisation will feed the world in 2050 given the threat of climate change and a growing population.*

This column appears monthly. Up next week: Chanda Prescod-Weinstein

ONE thing that has always fascinated me is the concept of food taboos. While those of other cultures can seem quirky and colourful to our minds, we can often forget that we have several of our own. These don't stay still as cultures evolve either, and the introduction of novel foods can often be accompanied by new foodie fears. If my inbox is anything to go by, there is one that seems to be gathering pace in the West: the idea that seedless fruits are dangerous.

For those unfamiliar with this belief, it seems to go as follows. The whole biological function of fruit in nature is to distribute the seeds of the plant to ensure the survival of the species. When fruits are seedless, however, it is meant to be a sign that they have been nefariously manipulated to abandon their basic biology by industrial agriculture, rendering them of lower nutritional value. According to more extreme proponents of this view, these fruits not only have an inferior vitamin and mineral content, but are actually harmful.

Typing the term "seedless fruit" into an internet search engine presented me with the suggested search terms of "bad", "bad for you", "good or bad", "GMO" and even "bible". If you are curious about the last one, there appears to be a relatively large section of the internet that views seedless fruits to be against the teachings of the bible and, in particular, anti-abortion beliefs, meaning to some people seedless fruits aren't just unhealthy, but unethical too. Given the controversy, let's take a closer look at what seedless fruits are and how they are produced.

Seedless fruits are the result of a biological process called parthenocarpy – the development of a fruit without prior fertilisation. While it is true that this can be the result of human actions, it also happens in nature all the time. Often, it is a combination of both.

For example, in the wild, banana fruit are filled with hard, ball bearing-like seeds that make them incredibly fiddly to eat, to the point of being essentially inedible. Archaeological evidence suggests a naturally occurring hybrid between two banana species that produced infertile offspring was noticed by the Palaeolithic peoples of South-East Asia and Melanesia for its much tastier, better-quality fruit. By splitting off the baby plants that bananas naturally produce around their base and replanting them, it is thought they were able to spread clones of this new wonder plant via dugout canoe all the way from Papua New Guinea to India, the Middle East and the eastern coast of Africa thousands of years ago.

> **"Palaeolithic peoples in South-East Asia spread clones of a naturally seedless banana plant around the world"**

Similar events have occurred in a wide range of fruits with a pretty ancient heritage. This includes "Thompson Seedless" grapes, which dominate world trade. This variety is frequently cited as a classic example of modern genetic manipulation, when in reality it is a modern US trade name for a Turkish cultivar that dates back to at least the early Ottoman Empire. The development of genetically sterile hybrids continues today, with the comparatively modern invention of seedless watermelons, for example.

However, genetic crossing isn't necessary to produce seedless fruit. In some cases, perfectly fertile plants will produce seedless fruit in the absence of pollination. Some citrus farmers will net their trees in a fine mesh to prevent bees from pollinating the flowers, resulting in seedless fruit, but there is an even simpler way to do this. Some varieties of fruit are naturally self-sterile and will only produce fruit with viable seeds if crossed with a genetically different variety. Many pineapples, for example, are made seedless by simply growing one variety in a field, kept away from the partners they need to produce viable seeds.

Finally, there are chemical interventions that can be used to induce seedless fruit, but these make up only a tiny percentage of the market.

But what effect does the lack of seeds have on nutrition? Well, seeds do often contain nutrients like fibre, which can mean seed-containing fruits are, gram for gram, slightly higher in fibre. They can also contain potentially beneficial phytonutrients like polyphenols. This, however, assumes you not only consume the seeds, but crunch into them with your teeth to release these compounds in a digestible form. When was the last time you munched on all the seeds in a non-seedless orange or grape variety instead of spitting them out?

Then there is the question of popularity. It doesn't matter how nutrient-packed a crop is if people are unwilling to eat it. While the nutritional difference between seeded and seedless is minimal, we know that the consumption of grapes and citrus fruits has greatly increased since seedless forms were introduced. So when seen in this crucial, wider context, rather than being a net loss for nutrition in our diets, seed-free fruits have been a net gain. ▮

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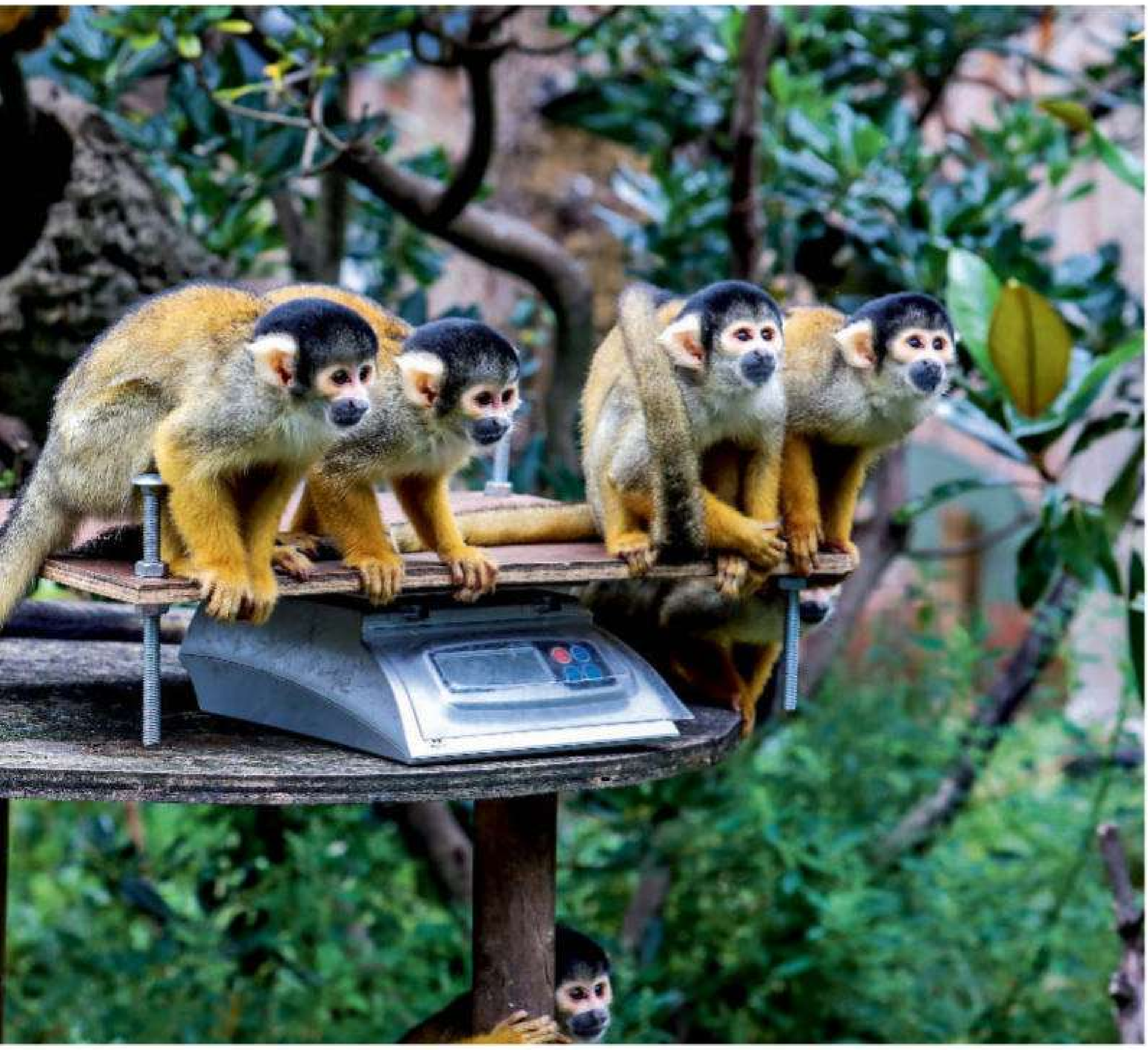

Measuring time

Photographer **Brett Cove/ZSL**

THESE charming residents of London Zoo, run by the Zoological Society of London, are just a few of the 20,000 animals that are being weighed and measured as part of its annual weigh-in.

Recording heights and weights helps zookeepers keep tabs on each animal's health and well-being, such as whether they are growing at the appropriate rate, as well as to monitor or detect pregnancies.

However, since it isn't always easy getting the animals to remain in one place to be measured, tactics often need to be deployed to get them to stand or stay still.

One way to do this is through play. The image on the far left shows Arya, an Asiatic lioness who arrived at the zoo in April, stretching out against a giant ruler after being enticed with a ball.

In the image at the top right, these Bolivian black-capped squirrel monkeys have been encouraged to climb onto the scales with treats. Below this, on the left, huge callipers are needed to measure Polly the Galapagos tortoise's shell, while at the other end of the scale, the weigh-in for a midwife toad (bottom right) requires only a spoon-sized instrument.

Gege Li

Editor's pick

Keep an open mind on the quantum realm

28 August, p 34

From Kate Hopkinson, London, UK

I appreciated your overview of the current frontiers in quantum theory. One recurrent problem seems to be the lack of success in harmonising the classical, dichotomous logic of the macro world with the unusual logic that seems to "run" the quantum realm.

In fact, different varieties of logic have been known for some time: philosopher Susan Haack wrote an extremely interesting book on them called *Deviant Logic, Fuzzy Logic*. This leads me to wonder whether the implicit assumption that there is one correct logic (and that Cartesian logic is it) may not be helping us.

The texture and dimensionality of conscious experience may be so rich that it can encompass numerous different logics that work from different perspectives – even, perhaps, different families of logics.

Just as geometry has turned out to consist not just of Euclidean geometry, but other geometries too, it seems that it would be worth at least exploring the possibilities more thoroughly, instead of trying to bludgeon the logic of the quantum world into uncomfortable compliance with the world we know.

From Hugo Whately, St Briavels, Gloucestershire, UK

The introduction to your feature on all things quantum talked of "a wilderness of interpretation where physics begins to blend into philosophy", but there was no mention of Immanuel Kant and his idea that the true nature of such things may elude us. For example, Kant's point that what we see depends not just on how we look, but on how we are able to look may reflect the quantum realm's wave/particle duality.

The article ends on the need for a theory that goes deeper than quantum. Perhaps the next great step in physics may have less to do with faithfully and completely representing the universe and more to do with faithfully and completely representing our experience of the universe. We may not, after all, ever escape our human way of being in the world.

Genetics may offer a way to speed carbon drawdown

21 August, p 41

From Geoff Harding, Sydney, Australia

When it comes to actively sucking carbon out of the atmosphere, the genetic modification of crops and trees may be a key technology.

Any such change to crops ought to aim to increase yield and resistance to disease and insects, as well as improve adaptation to a changing climate. The enhanced food yield will address the issues of a growing population, but most importantly in the context of carbon removal, it should also let us reallocate considerable areas of agricultural land for forest growth. Genetic modification of trees should try to speed up growth and improve adaptation to a changing climate, possibly including greater resistance to fires.

A model approach for all those modellers

21 August, p 32

From Robbie Morrison, Berlin, Germany

In his review of the book *Atlas of Forecasts*, Simon Ings rightly questions the value of increasingly complex mathematical models that shape public policy, and hence our lives, but that only experts can understand.

Worse still, those outside the teams that build and run these models have limited ability to evaluate the work, unless the software is open source, the data genuinely open and available, and the documentation public.

A number of energy-system modellers, through the Open Energy Modelling Initiative, have been working hard to achieve open analysis within our domain. Indeed, open by default may soon be the analytical norm for Europe. Instead of opaque trust, we offer transparency, reproducibility, inclusion and collaboration. Feel free to help us curate system data, explore net-zero energy futures and assist with outreach.

Political no-show over climate is no big shock

21 August, p 25

From William Hughes-Games, Waipara, New Zealand

Environmentalist Jonathon Porritt notes that "neither extreme weather nor stronger warnings in Intergovernmental Panel on Climate Change reports has triggered a proper emergency response from politicians". This isn't surprising – as long as politicians are beholden to vested interests for election campaign funds and sweet jobs when they leave office, they will do the bidding of the vested interests. Who pays the piper calls the tune.

Beaming solar from space is just pie in the sky

28 August, p 17

From Rachael Padman, Newmarket, Suffolk, UK

Talk of solar panels in space is one of those ideas that won't die, but should. The only reason to use a space-based system is to ensure uninterrupted supply. It would be far cheaper and much less dangerous to instead invest in terrestrial solar with energy storage that could power the grid at night and on really cloudy days.

From Ron Todd, Yate, Gloucestershire, UK

If we are to beam down 2 gigawatts of power from solar panels in space, I propose that the receiver for this high-energy beam is put next to the house of the person who approves the systems that keep it pointing at the right spot.

On the prospects for life inside caves on Mars

4 September, p 9

From Armando Azua-Bustos, Centre of Astrobiology, Madrid, Spain

You report research that suggests life may be viable inside Martian caves. My colleagues and I tested this idea in our 2009 paper "Ancient photosynthetic eukaryote biofilms in an Atacama desert coastal cave".

The study you describe suggests that UV radiation levels are low enough inside Martian caves to be relatively safe, but high enough to sustain organisms that require light to produce energy via photosynthesis. We showed this was the case, and commented in our paper that "our findings could be placed in an astrobiological context of a Martian cave, where a hypothetical phototrophic microorganism... could be found inside a cave well protected from the harsh outside conditions using minimum photon flux levels coming from a nearby entrance, but high enough for enabling the photosynthetic processes critical for survival".

Spread this little serving of wisdom

28 August, p 51

From Pamela Ross, Findochty, Moray, UK

Further to Sam Wong's article on the science of jam making. A good tip is that slightly under-ripe fruit contains more pectin, eliminating the need to add pectin via either special jam sugar or apples. ▮

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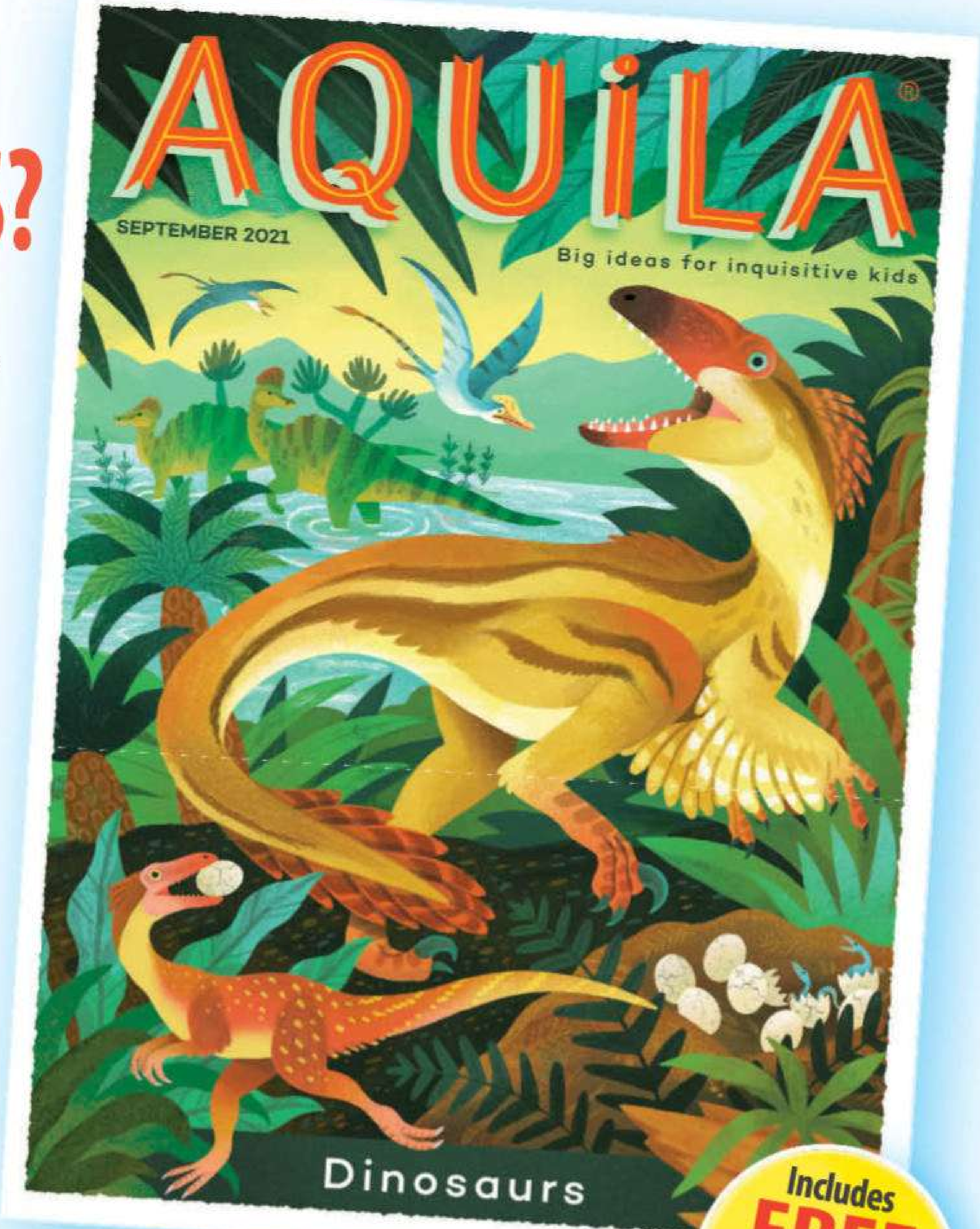
Free-range DINOSAURS?

AQUILA is a thoughtful and intelligent children's publication, where serious facts are blended with a special kind of humour and fun: well written and well loved, this month's topic is one that children can really get their teeth into.



This month's magazine

What's your favourite dinosaur fact? Here are a few of ours at AQUILA HQ: One of the largest dinosaurs known is called **Dreadnoughtus** – a 26 metre-long sauropod weighing 65 tons (that's 11 African elephants). The tallest dinosaur on record is **Sauroposeidon**. Its name means *'Lizard Earthquake God'*!

In this issue children can read about **Chaos theory** as we investigate the work of *Edward Lorenz* and **The Butterfly Effect**; help Professor **Teri Dactyl** locate her favourite spade in the **Brainfeeders** puzzles and find out what kind of dinosaur they are in our fun quiz – an angry, bitey T-rex, a steady steggy, or a super-chilled diplodocus?

The Call of the Wild: Scientists know quite a lot about how dinosaurs looked, but **how did they communicate?** Did they squeak, purr or roar? And did they show-off with flamboyant displays to catch a mate, as some modern-day birds do? We also debate the **Chickenosaurus conundrum**: could genetic engineers turn a chicken into a dinosaur? And supposing they could – *should they*?

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Mark Maslin Professor of Earth System Science, University College London

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Tristan Smith Associate Professor, University College London

NINE HARVESTS TO RESTORE THE EARTH

Sean Westcott Senior Vice President R&D Europe, Pepsico

NET ZERO BUILDINGS

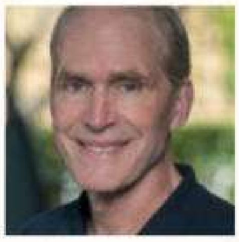
Catalina Spataru Head and Director of Islands Laboratory, UCL Energy Institute

RE-THINKING THE ZERO CARBON TRANSITION

Nick Eyre Director, Centre for Research into Energy Demand Solutions

PEOPLE AND PLANET STAGE

Discover inspiring ways to restore the environment and how you can lead your greenest life



RESTORING THE ATMOSPHERE

Rob Jackson Professor, Earth and Environmental Sciences, Stanford University

BT'S SMARTER LIVING CHALLENGE

Julia Denham Environmental Sustainability Manager, BT and **Jess Wiles**, Senior Creative Partner, Hubbub

CHANGE YOUR DIET: THE EASIEST WAY TO REDUCE YOUR CLIMATE IMPACT

Sarah Bridle Professor, Extragalactic Astronomy and Cosmology Research Group, Jodrell Bank Centre for Astrophysics

Wit and wildlife

Few writers have the ability to make any subject as fun and interesting as Mary Roach does. Her new book is no exception, says **Tiffany O'Callaghan**

Book

Fuzz: When nature breaks the law
Mary Roach
WW Norton

MARY ROACH has a knack for choosing subjects for her books that won't have necessarily crossed your mind and convincing you that you must now know everything about them. She has covered the logistics of strapping cadavers into cars to use as human crash test dummies (*Stiff*), how studying what orgasms look like in the brain requires people to get busy in an MRI scanner (*Bonk*), pondered the literal ins and outs of what competitive eating does to your digestive tract (*Gulp*) and contemplated how astronauts poop in space (*Packing for Mars*, a rare deviation from her single word titles).

In her new book, *Fuzz: When nature breaks the law*, her subject is the unfortunately now familiar issue of human-wildlife conflict. But she hasn't decided to switch gears and approach her subjects from a place of earnest lamentation, in this case about the perils of our encroachment on wild habitats. Instead, with her characteristic dry wit, she brings an intense fascination to the seldom discussed details and the at times absurd miscellany in the unexplored corners of unappreciated research.

The opening chapter finds her at a wildlife forensics conference, where she learns about what happens after a human is mauled by a wild animal. The focus of the Wildlife-Human Attack Response Training conference is mainly bears in the Pacific Northwest. We learn that very often the culprit is identified and killed, but occasionally the backwoods whodunnit turns up a surprise: a "gnawed on corpse" is no smoking gun. An opportunistic omnivore does occasionally stumble on a human already dead from other causes.

Each chapter explores a new type of conflict, from elephants that stomp their way across crops (and people) to albatrosses that get sucked into jet engines, leopards that attack people to deer that collide with aircraft (yes, you read that right).

Along the way you pick up plenty of helpful tips. The best makes of car if you plan to survive crashing into a moose? Saab or Volvo. The most cost-efficient way to keep birds from eating your harvest on a small farm? Humans regularly chasing them off.

> "It's impossible not to smirk, chortle and sometimes outright belly laugh as you read the many wry asides"

As to whether you should stay still or fight back in a hostile bear encounter, it largely depends on what kind of bear it is, "black fight back, brown lie down" as the ditty goes. The trouble is, as Roach points out, some brown bears' fur can be black, and some black bears look pretty brown.

"A more reliable way to distinguish the two is by the length and curvature of their claws," she says, before conceding that, "by the time you're in a position to make that call, the knowledge will be of limited practical use."

It is impossible not to smirk, chortle and sometimes outright belly laugh as you read her many wry asides and funny but fascinating footnotes.

A particular favourite for me has to do with the surprisingly persistent myth that birds will explode if they eat the rice tossed at weddings: "Some churches ban the practice anyway, not because it's perilous for birds but because it's perilous for guests, who could slip on the hard, round grains and fall and then fly off to a personal injury lawyer."

She provides an ample supply of factoids to regale your friends with. Did you know that it is our "looming sensitivity" that helps us and other animals anticipate how fast something is coming at us, so we can get out of the way? (Or not, see the earlier mention of deer and aircraft.)

But the real trick Roach pulls off is to keep you laughing while at the same time making sure the earnest points come across. Among the many that stuck with me is that before the 1980s, wildlife and wilderness were conserved in the US to provide good hunting and fishing. It is only recently that "conservation" has been about protecting these areas and creatures for their own sake. ■

WANG ZHENGPENG/VCG VIA GETTY IMAGES

A herd of wild Asian elephants strolls through a village in China

Cabinet of curiosities

A stranger and a collection of unusual objects is enough to make a city's protector rethink their position, finds **Bethan Ackerley**

SHUTTERSTOCK/TITHI LUADTHONG

A complex network called the Gleaming watches over the town of Ora via a huge inverted tree

Book

In the Watchful City
S. Qiouyi Lu
Tordotcom

MODERN life is built around the accumulation of objects: some valuable, some not, and most entirely unnecessary. But which, if any, of your possessions could represent the core of who you are? In S. Qiouyi Lu's debut novella, each item in a mismatched collection of curios is a window into a defining moment of another person's life.

***In the Watchful City* is set in Ora, an isolated metropolis at the heart of a cloud forest. Ora's society is vibrant, comprising people of many cultures, genders and even mythical species, but its citizens are monitored via the Gleaming, a complex network that integrates qì – the vital force of all living things – with vast amounts of data. The Gleaming is channelled through the Hub, an enormous, inverted tree that acts as a database for the all-encompassing surveillance state.**

Yet neither Ora's governance nor the lives of its citizens is the focus of *In the Watchful City*. It instead follows the inner turmoil of Anima, a "node" who is rooted to the Hub's inner sanctum, who can manipulate the Gleaming by slipping into a *Minority Report*-style amniotic bath. It is Anima's job to watch over the city, be that by scouring for evidence of financial crimes or by borrowing the bodies of animals to chase down fugitives.

Anima – who uses the non-binary neopronouns ae/aer – has always lived in Ora and has been both unable and unwilling to physically leave the Hub since ae became a node as a child. All that changes when a mysterious stranger called Vessel arrives at the Hub with a qíjìtáng, a cabinet of curiosities from far-flung places; the items range from rarities like a bone marionette and a mermaid's scale to a simple bundle of letters.

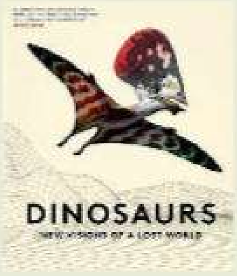
***In the Watchful City* is a mosaic novella: for every object in the qíjìtáng that Anima observes, we get a glimpse of another story from the lands outside Ora. Some of these tales feel relatively disconnected from the main narrative, like *A Death Made Manifold*, in which a man goes to extraordinary lengths to resurrect his late brother. Others may help explain why Ora's society is so isolated. *This Form I Hold Now*, for instance, reveals more about the cultural imperialism of the Skylanders, a federation in the clouds that has colonised many nations on the planet's surface.**

Though the novella takes a little time to show its full potential – the opening pages bombard you with details about Anima and Ora, while the first of the qíjìtáng's tales is the weakest – Lu has crafted an impressive mythos that draws from the traditions and legends of a variety of cultures, especially Chinese folklore. Take *The Sky and Everything Under*, a bittersweet tale that describes an imperial duarchy based on Chinese myths of one-winged birds, dependent on each other for flight. But these lofty allusions are leavened by rich, joyful descriptions of everyday life; a lengthy depiction of an outdoor food market viewed through the eyes of a hungry dog is a particular highlight.

It comes as little surprise, then, that Anima grows more and more intrigued by life outside the confines of Ora. Readers expecting a thorough analysis of the city's surveillance culture will be disappointed; Lu is more concerned with the psychological effects of Anima's isolation than the system that necessitates aer physical confinement.

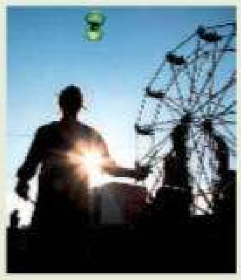
Such details could have been fleshed out in a longer narrative, and more than once I found myself wishing that certain events, like Anima witnessing the death of a stranger, had been given more room to breathe. But I suspect that, much like the effect the tales of the qíjìtáng have on Anima, *In the Watchful City* will linger all the more for being an incomplete picture. ▮

Don't miss



Read

The Dinosaurs: New Visions of a Lost World are conjured by palaeontologist Michael Benton and palaeoartist Bob Nicholls, showing how advances in technology have changed the way we see these beasts forever.



Visit

HowTheLightGetsIn festival brings deep thought to the grounds of Kenwood House in London on 18 and 19 September. Explore the temptations of rewilding, the seductiveness of memes and other hot topics. Also streamed online.

Watch

Autism and Cinema, at London's Barbican Centre from 16 September, hosts a series of films, including *Temple Grandin* (pictured), a biopic about the animal behaviour researcher and activist of the same name.

HOW THE LIGHT GETS IN; NICK TREHARNE/ALAMY

The film column

Keep quiet and fight the robot apocalypse

A New World Order follows two people caught in a war against the machines. It has no dialogue and shows just how powerful films without dialogue can be, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram @simon_ings

REEL 2 REEL FILMS

In *A New World Order*, military robots have turned on humanity

Film

A New World Order

Daniel Raboldt

Digital release

"FOR to him that is joined to all the living there is hope," runs the verse from Ecclesiastes, "for a living dog is better than a dead lion." Stefan Ebel plays Thomasz, the "living dog" in *A New World Order*. He is a deserter who, out of necessity, has learned to look out solely for himself.

In the near future, military robots have turned against their makers. The war seems almost over. Perhaps Thomasz has wriggled and dodged his way to the least settled part of the planet (Daniel Raboldt's debut feature is handsomely shot in Arctic Finland by co-writer Thorsten Franzen). Equally likely is that this is what the whole planet looks like now: trees sweeping in to fill the spaces left by an exterminated humanity.

You might expect the script to make this point clear, but there is no script, or rather, there is no dialogue. The machines (wasp-like drones, elephantine tripods and one magnificent airborne battleship that wouldn't look out of place in a Marvel movie) target people by listening out for their voices. Consequently, not a word can be exchanged between Thomasz and his captor Lilja, played by Siri Nase.

Lilja takes Thomasz prisoner because she needs his brute strength. A day's walk away from the questionable safety of her log cabin, there is a burned-out military convoy. Amid the wreckage and bodies, there is a heavy case – and in the case is a tactical nuke. Lilja needs Thomasz's help in dragging it to where she can detonate it, perhaps bringing down the machines. While Thomasz acts out of fear, Lilja is acting out of despair. Both are reduced to using each other. Both will have to learn to trust again.

> **"The film's sound design is striking, even a car's gear change comes across as an imminent alien threat"**

In 2018, John Krasinski's *A Quiet Place* arrived in cinemas – in which aliens chase down every sound and slaughter its maker. This can't have been a happy day for the devoted and mostly unpaid German enthusiasts working on *A New World Order*. But such "silent" movies are no novelty, and theirs has clearly ploughed its own furrow. The film's sound design, by Sebastian Tarcan, is especially striking, balancing levels so that even a car's gear change comes across as an imminent alien threat.

Writing a good silent film is something of a lost art. It is much easier for writers to explain their story through dialogue than to propel it through action. Maybe this is why silent film, done well, is such a powerful experience. There is a scene in this movie where Thomasz realises not only that he has to do the courageous thing, but that he is at last capable of doing it. Ebel, on his own on a scree-strewn Finnish hillside, plays the moment to perfection.

Somewhere on this independent film's long road to distribution – it began life on crowdfunding platform Kickstarter in 2016 – someone decided "A Living Dog" was too obscure a film title for these godless times. It is a pity, I think, and not just because *A New World Order*, the title picked for UK distribution, manages to be at once pompous and meaningless.

Ebel's pitch-perfect performance drips guilt and bad conscience. In order to stay alive, he has learned to crawl about the earth. But Lilja's example, and his own conscience, will turn dog to lion at last, and in a genre that never tires of presenting us with hyper-capable heroes, it is refreshing, on this occasion, to follow the forging of one courageous act. ▮

Simon also recommends...

Film

The Last Battle (1983)

Another debut with no dialogue, this time by Luc Besson. This mysterious, post-apocalyptic adventure, filmed in derelict corners of Paris, conjures up a future in which humanity has lost its powers of speech.

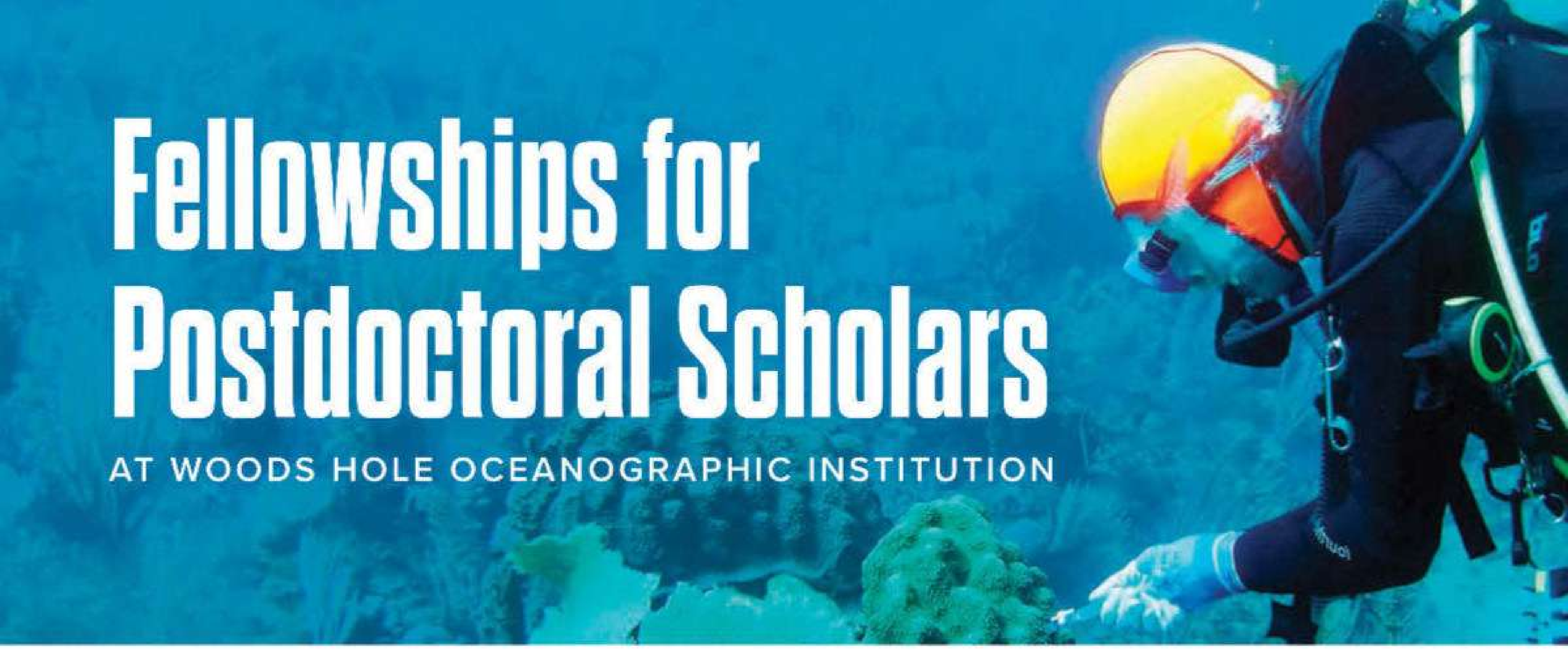
Book

Hope Island

Tim Major

Titan Books

This horror-sci-fi hybrid unpicks the sonic mysteries of a small island in the Gulf of Maine. It is a spine-tingling tale of screams and susurration and all manner



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https://go.whoi.edu/pdscholarship

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SHUTTERSTOCK

Living by the numbers

People are told to aim for 8 hours sleep, 10,000 steps, eight glasses of water and a fixed number of calories, but are these targets useful? **Amelia Tait** investigates

FOR as long as I can remember, certain numbers have inhabited my head: Five fruit and veg a day, 8 hours of sleep, 2000 calories, 2 minutes of tooth brushing, eight glasses of water, 10,000 steps.

For want of a better term, these are the "recommended dailies": numbers that are etched onto our brains as the ones we should live by. But for all their influence, it is unclear whether sticking dutifully to them actually makes a difference to our health. So I decided to get to the bottom of things, attempting to live my own life by the numbers (see "Living the dream", page 41) while also digging into some critical questions about them: who came up with these figures in the first place? How solid is the scientific basis for these magic numbers? More to the point, is sticking to them really worth the effort?

Brush your teeth for 2 minutes, twice a day

Keeping your teeth clean isn't just a way to avoid the dentist's drill (and bill) – the bacteria that cause gum disease have also been linked to an increased risk of developing Alzheimer's. People with gum disease also have a two to three times greater risk of having a stroke or heart attack, and while a causal link hasn't been shown, there are suggestions that gum disease increases markers of inflammation in the blood.

The benefit of brushing is that as it removes thin films of plaque bacteria from the teeth, it breaks up bacterial communities, disrupting the opportunity for social evolution. This essentially stops them evolving into super bacteria that are experts at causing decay.

Where the "rule" about brushing for 2 minutes, twice a day comes from isn't clear (Public Health England is unsure of its origins, despite the recommendation appearing on National Health Service sites), and there is conflicting evidence on how much, and how often, is actually needed.

A 2005 review by the Department of Operative Dentistry at the University of Göttingen in Germany concluded that brushing once a day could be sufficient for good oral health, but argued that since most people aren't particularly thorough, twice a day is probably better.

As for how long to brush, in 2012 the Academic Centre for Dentistry Amsterdam, in the Netherlands, looked at this and showed that when people brushed for 2 minutes, they removed around 41 per cent of the plaque on their teeth, while those who brushed for 1 minute removed just 27 per cent.

Unfortunately, 41 per cent is still quite low, which perhaps suggests that we should brush for even longer. A 2009 article in the *Journal of Dental Hygiene* found a clear dose-response relationship between brushing time and plaque removal, noting that "even after 3 minutes of brushing, some plaque removal still appeared to be occurring".

Yet, as we all know from TV advertising, only nine out of every 10 dentists agree. Santosh Kumar Tadakamadla, a research

fellow at Griffith University's School of Dentistry and Oral Health in Australia, says that some researchers argue that brushing with hard bristles can damage the teeth by causing erosion. But with the British Dental Health Foundation reporting in 2010 that the average person in the UK brushes for just 45 seconds a day, more is probably better for most people.

Although people who have prior experience of tooth decay or who consume a lot of sugar between meals might need to brush more than others, Tadakamadla says that 2 minutes twice a day should be fine, particularly when paired with fluoridated toothpaste to protect the enamel.

Take 10,000 steps

In the mid-1960s, a small, plastic pocket watch-like device went on sale in Japan. Called the "manpo-kei", it was the world's first commercial pedometer. Roughly translated, manpo-kei means "10,000 steps meter".

Why 10,000? "It likely originated as a marketing tool," says I-Min Lee, an epidemiologist at Harvard University. Not only is 10,000 an easy number to remember, the character for 10,000 in Kanji, a script used in Japanese, looks a little like a person walking.

This health target, then, didn't originate with science. Can we scrap it and have a nice sit down? Herman Pontzer, an evolutionary anthropologist at Duke University in North Carolina, studies the Hadza, hunter-gatherers in Tanzania, as a window into how humans lived thousands of years ago, and the levels of activity our bodies were built for. In a recent study, he measured more than 2000 days of Hadza activity, and found that Hadza men aged 18 to 75 walked on average 18,434 steps a day, while women in the same age range walked 10,921. The Hadza tend to avoid many of the chronic illnesses of Western societies that are related to inactivity.

So should women dedicate time and energy to getting those extra 921 steps? Perhaps not. In a 2019 study, Lee and her colleagues found that women who averaged 4400 steps a day had lower mortality rates than those who took fewer than 3000 steps. Mortality rates decreased as step rates increased up until around 7500 steps, beyond which no additional mortality benefit was observed.

Lee's study only examined mortality – not quality of life – and she doesn't want to dissuade anyone who does get their 10,000 steps. "Stepping more is better, but we don't necessarily need to reach that 10,000 number," she says. She studied older women, but says her findings are applicable to "a broader group of people who aren't very active".

Another thing worth remembering is that the step counter on your wrist or in your pocket doesn't really measure steps at all, but the motion of your hands or hips. According toTessa Strain at the University of Cambridge, who studies the epidemiology of physical activity, step counts are a rough proxy for energy expenditure, and what is really important is the amount of energy you expend. Not all steps, then, are created equal.

The rate of energy expenditure in a given task is given as a "metabolic equivalent" or MET. One MET is the energy expended at rest.

> **"The food we eat accounts for around 30-35 per cent of moisture intake"**

According to The Adult Compendium of Physical Activities, developed by William Haskell, a cardiovascular health researcher at Stanford University in California, walking slowly on level ground requires 2.8 METS; walking briskly, say at 3.5 miles per hour (5.6 km/h), is 4.3 METs; and walking briskly uphill accounts for 5.3 to 8 METs, depending on how steep the ground is.

The upshot is that if you have only done a few thousand steps but they were brisk and uphill, there is no need to walk around in circles to get to 10,000. And if you average nowhere near 10,000, the important thing to remember is that any steps are good, but at the lower end of the scale, more is better. In a 2020 paper, Strain found that the biggest differences in health risk were between those doing minimal amounts and those doing slightly more. "I think recent efforts to promote the message 'every move counts' as strongly as an actual number is a really positive thing because I think it better reflects what we know about the association, and it is a universally understood message," she says.

In short, don't burn your trainers, try to move more and don't forget that 10,000 steps was originally a marketing ploy.

Drink eight glasses of water

Whether you are walking 10,921 or 4400 steps a day, you will need to keep hydrated: but is it necessary to gulp down eight glasses of water every 24 hours? Water is clearly important stuff: it delivers nutrients and flushes out waste, helps cells maintain their shape, lubricates our joints and helps to regulate body temperature. It also keeps our brains working at full capacity. According to a 2018 study from the Georgia Institute of Technology, 2 hours of vigorous gardening in the sun without drinking can be enough to impair our cognitive functions. But do we really need eight glasses a day, no matter what?

That figure dates back to 1945, when the US Food and Nutrition Board of the National Research Council published dietary guidelines that recommended consuming 1 millilitre of liquid for every calorie of food consumed. That adds up to 2 litres of water a day for those on a 2000-calorie diet.

Yet Tamara Hew-Butler, an exercise scientist at Oakland University, Michigan, says the guidelines were misunderstood. "That recommendation included all of the fluids in fruits and beverages, it wasn't just

›

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about drinking water," she says. In fact, much of our water intake comes from the food we eat. Population surveys from France and the UK published in 2016 found that food accounts for around 30 to 35 per cent of moisture intake.

The 2-litre recommendation wasn't just misunderstood: over time, it was simplified into eight glasses of around 250ml each, or 8 × 8 ounces glasses as per widely quoted in the US version. Hew-Butler believes bottled water companies capitalised on the misconception.

How much topping up we actually need varies considerably. For people with a history of kidney stones or bladder infections, the data supports aiming for 2 litres a day – but for everyone else it varies. "How can one particular recommendation be good for everybody?" says Hew-Butler. "If you're bigger, if you're more active, and if it's hotter outside, you're going to need more."

The answer to how much more comes from an oft-ignored line in the original 1945 report, which stated that "sensations of thirst usually serve as adequate guides to intake except for infants and sick persons".

Our bodies are set up to take care of this without the need to count glasses, says Hew-Butler. "The gene that governs water balance, it's been conserved in nature for 700 million years – it's in worms, it's in insects, it's in every mammal out there," she says.

The main hormone that governs water balance is the antidiuretic hormone vasopressin, or AVP. In mammals, AVP participates in a feedback loop between the brain and kidneys, so that when the body loses water, AVP is secreted by the brain, which signals the kidneys to produce less urine. Thirst is activated once the kidneys have conserved all the water possible. If we drink more water than we need, then the brain stops the production of AVP and more urine is produced and we spend a lot more time in the bathroom.

If you really want to put a number on your water intake, says Hew-Butler, you could estimate the energy used during exercise and aim to take in 1 millilitre of water for every calorie burned. Drinking when you are thirsty, she points out, is far simpler.

Get 8 hours of sleep

Eight is clearly an appealing number – as well as glasses of water per day, it is often touted as the magic number of hours of sleep per night for optimum health.

This, at least, does seem to be based on research. While the number of hours varies from person to person, says Ciro della Monica, research fellow at the University of Surrey's Sleep Research Centre, "Eight hours is an average ideal for a healthy adult".

> **"There is tentative evidence that too much sleep can be harmful"**

Sleep isn't just satisfying – it's a matter of life and death. Rats deprived of sleep die within a month and, in humans, insufficient sleep has been shown to impair physical and cognitive performance, impact mood, reduce alertness and worsen reaction time. In the longer term, insufficient sleep has been linked to dementia. Neuroscientist Maiken Nedergaard at the University of Rochester, New York, suggests that sleep activates a waste-disposal network in the brain that flushes out harmful metabolic debris, including amyloid protein, the build-up of which is associated with Alzheimer's disease.

Multiple studies have also linked how much sleep you get and lifespan. While it varies a bit from the 8-hour recommendation, a 1964 study of more than 1 million adults conducted by the American Cancer Society found that men who got 7 hours of sleep had lower death rates over the following six years than those who slept less or more, with those who slept just 5 hours experiencing "very high death rates". This link has since been observed many times.

There is clearly some leeway in the 8-hour rule. Jerome Siegel, a sleep researcher at the University of California, Los Angeles, has studied pre-industrial societies in Tanzania, Namibia and Bolivia, and found they sleep on average between 6 and 7 hours – finding a "striking uniformity" across the groups.

According to a poll by YouGov, only a third of Britons are getting at least 7 hours of sleep per night. A 2018 study from Western University in Ontario, Canada, suggests that these people are at an advantage, cognitively speaking. In a survey of more than 40,000 people, 7 to 8 hours of sleep proved to be optimum for cognitive function, while participants who got just 4 hours nightly performed as if they were almost 8 years older than they were.

On the other hand, there is tentative evidence that too much sleep can also be harmful. Long sleep duration has been associated with increased mortality rates, cardiovascular disease, diabetes, stroke, coronary heart disease and obesity. Correlation isn't causation, though, says della Monica. It hasn't been shown if long sleep causes these health outcomes or if they are consequences of underlying diseases.

Intriguingly, some lucky people can get away with very little sleep without the biological consequences. In 2019, biologist Ying-Hui Fu at the University of California, San Francisco, found two DNA mutations, in genes called *ADRB1* and *NPSR1*, that allow people to thrive on just 4 hours of sleep. Fu found the genes by studying families who reported feeling fully rested after much less sleep than normal. When she engineered the *NPSR1* mutation into mice, they slept less, but their memory and health didn't seem to be impaired. Fu speculates that these mutations could be very recent and therefore may continue to spread. So, while in the distant future people may be able to sleep less than you and stay healthy, for now we should aim for at least 7 hours.

Living the dream

For one week only, I ticked all the boxes. I stuck to 2000 calories, ate my greens, guzzled water and went to bed on time.

At the end of day one I had a headache, was fed up of counting glasses of water and frustrated because needing to pee kept interrupting my 10,000 steps.

On day two, though, I started to feel the benefits: I felt less bloated than usual, and was noticeably happier and more energised. By the end of the week, my leg muscles felt tighter from all the walking, but I was contemplating setting fire to the world's supply of kale.

Overall, it was a success, but it required constant effort, and I'm not sure I could keep it up for the years that research-based health outcomes are based on. Still, a few weeks after my experiment, I have managed to stick to a more manageable 7500 steps a day, ensuring at least some of them are vigorous. Two minutes of toothbrushing, feels like half an hour and who has the time? I leave my water and my sleep up to my body. I leave kale alone, full stop.

Eat five a day

Everyone knows they should be eating five portions of fruit and veg a day, yet according to government surveys, only 28 per cent of English adults and 10 per cent of those in the US manage it. Which makes the 2017 finding from researchers at Imperial College London, that 10 a day is even better, seem even less achievable.

The five-a-day figure is based on the World Health Organization's recommended daily minimum of 400 grams of fruit and veg. Five a day comes from taking 80 grams as an approximate serving of fruit or veg – it is the weight of a small orange, a handful of blueberries or a carrot, for example. According to the WHO, this figure was based on "epidemiological evidence of an increased risk of cancer with low intakes of certain fruits and vegetables and their contributions to micronutrients as well as to dietary fibre".

In the 2017 analysis by the Imperial College team, led by Dagfinn Aune, however, eating 800 grams (or 10 portions) of fruit and veg a day was preferable to the well-established five, with the team estimating that this change could prevent 7.8 million premature deaths globally every year.

The group found that compared with someone who ate half a serving of fruit or vegetables a day, people who ate five a day saw a 14 per cent drop in risk of coronary heart disease, while people who ate 10 had a 24 per cent reduction. Similar patterns emerged for stroke and heart disease – when it came to all-cause mortality, five-a-day-ers had a 24 per cent reduction in risk compared with half-a-portion-ers, while 10-a-day-ers had a 31 per cent drop.

Aune stresses that if 10 a day feels overwhelming, do what you can. "It's important to note that we did see benefits even with modest intakes versus very low or zero intakes, so it is not about all or nothing," he says.

Aune's research also found that particular types of fruit and veg seemed more beneficial, including apples and pears, cruciferous vegetables like cabbage and kale, berries, and citrus fruits. Focusing on quality over quantity may be a better strategy than encouraging people to aim for a set number of portions, he suggests.

2000 calories

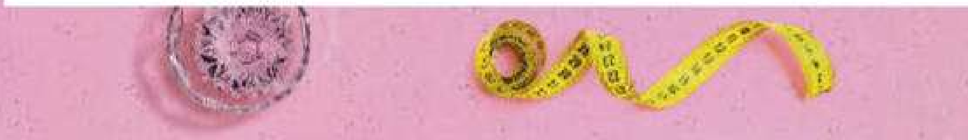
When it comes to what we eat in general, many of us are aware that we should be eating somewhere around the 2000-calorie mark. Pontzer, however, says that this is also a misconception. In his book, *Burn: The misunderstood science of metabolism*, Pontzer says that the figure originated in the 1990s when the US Food and Drug Administration (FDA) asked the nation to self-report their intake. In the study, women claimed to consume between 1600 and 2200 calories a day, while men confessed to eating anywhere between 2000 and 3000. The FDA pinned 2350 as the average and then rounded the figure down, further simplifying the message and to avoid overconsumption in women. Even in the original research, then, 2000 calories per day was an estimate.

On top of this, Pontzer says that people tend to systematically under-report their calorie intake by 20 to 30 per cent – "if you ask somebody how many calories they ate, it's basically a random number generator". When you actually measure how many calories people eat, says Pontzer, women actually take in closer to 2500 calories a day on average while men consume more like 3000. Is that a problem? Not necessarily.

When it comes to what we should eat, Pontzer argues that if your weight is stable, then "what you're consuming is also what you're burning". Needs vary from person to person based on our body mass and the demands we put on our bodies: for example, Pontzer estimates that a 45-kilogram gymnast with 10 per cent body fat would need 2200 calories a day. "The one-size-fits-all policy is have a look at the bathroom scale," he says.

Pontzer concedes that if you do manage to figure out your individual needs, then keeping track of your calories can be a helpful guide for maintaining a healthy weight and avoiding the slow creep of weight gain. The number 2000, however, isn't necessarily where the answer lies. ■

Amelia Tait is a freelance journalist based in London



When the chips are down

A new way of designing computer chips could be about to shake up one of the world's most secretive industries, says **Matthew Sparkes**

ON THE one hand was a perfect storm of problems hampering supplies: a global pandemic, a trade war, a blaze at a manufacturing plant and atrocious weather including drought and snowstorms. On the other was the unprecedented demand for one of the world's most sought-after products – a market worth $40 billion in January this year alone.

Even so, the news earlier this year that there was a global shortage of computer chips, pushing up the price of everything from laptops to fridges, took a lot of people by surprise. The crisis has seen nations and companies around the world scrambling to establish more chip-building capacity. It has also shone a light on an industry whose products have become ubiquitous and essential, leaving many to conclude that it is due a fundamental overhaul. For critics, the stranglehold on the market of just a few firms acts as a brake on innovation and increases the industry's vulnerability to disruption.

Some big names are now backing an alternative model – taking the collaborative, open-source principles that have changed the way software is written and applying them to chips. For its proponents, it is only a matter of time before this becomes the new standard. But when the chips are down, does it have what it takes – and what does it mean for us?

Computer chips are everywhere – not just in our laptops, desktops and smartphones. They are in the myriad mysterious servers that run our webmail, online bank and other digital services we use daily. They are in many microwaves, televisions, washing machines and watches. The average new car today contains hundreds of them.

Zoom in and one 60-year-old invention still lies at the heart of all these chips: the metal-oxide-semiconductor field-effect transistor, or MOSFET. The brainchild of Bell Labs researchers Mohamed Atalla and Dawon Kahng in 1959, it acts as a tiny switch that, wired up in specific ways, can perform basic logical operations like addition, subtraction or multiplication.

The very first processor chips were custom-designed, with transistors wired up with specific computational tasks in mind.

> **"We have begun to reach fundamental limits on the size of transistors"**

With computers becoming more complex and more commonplace, however, in 1964 IBM announced the IBM System/360, a mainframe computer that could run a range of different programs. Its processor came with a basic "instruction set" of operations – adding or comparing two numbers, say, or jumping to a certain spot in memory – from which more complex operations could be created.

The process of programming software that used these chips rapidly came to be assisted by tools to analyse, debug and verify code that was specific to an instruction set and the chip "architecture" underlying it (see "How chips work", page 46). That meant programmers no longer had to worry about how chips worked at the level of transistors. But it also meant handing a lot of power to a few established chip makers who provided well-understood, stable instruction sets and architectures.

That situation persists to this day. "The fact that [a chip architecture] has been there for that long means there's a whole built-in infrastructure," says Siva Sivaram at Western Digital, a company that creates hard discs storing 40 per cent of the world's data. "Lots of software is written on it, and operating systems have been sitting on top of it. Everybody knows what it is."

The main processors in your desktop or laptop computer, for instance, probably run on the x86 instruction set on chips designed by Intel or another US company, AMD, which initially reverse-engineered Intel's chips to create compatible designs. Data servers might use the IBM z/Architecture, which traces its lineage back to the System/360. Mobile phones often use ARM architecture, owned by a UK-based company that evolved from Acorn Computers. ARM has shipped more than 125 billion chips, making it one of the most successful architectures ever.

All these companies keep strict tabs on their intellectual property. Intel, for example, has the sole say-so over the design and manufacture of its chips. "You want an Intel processor... they're in control," says Cecil Macgregor at data storage company Seagate.

Designing and making new chips is, after

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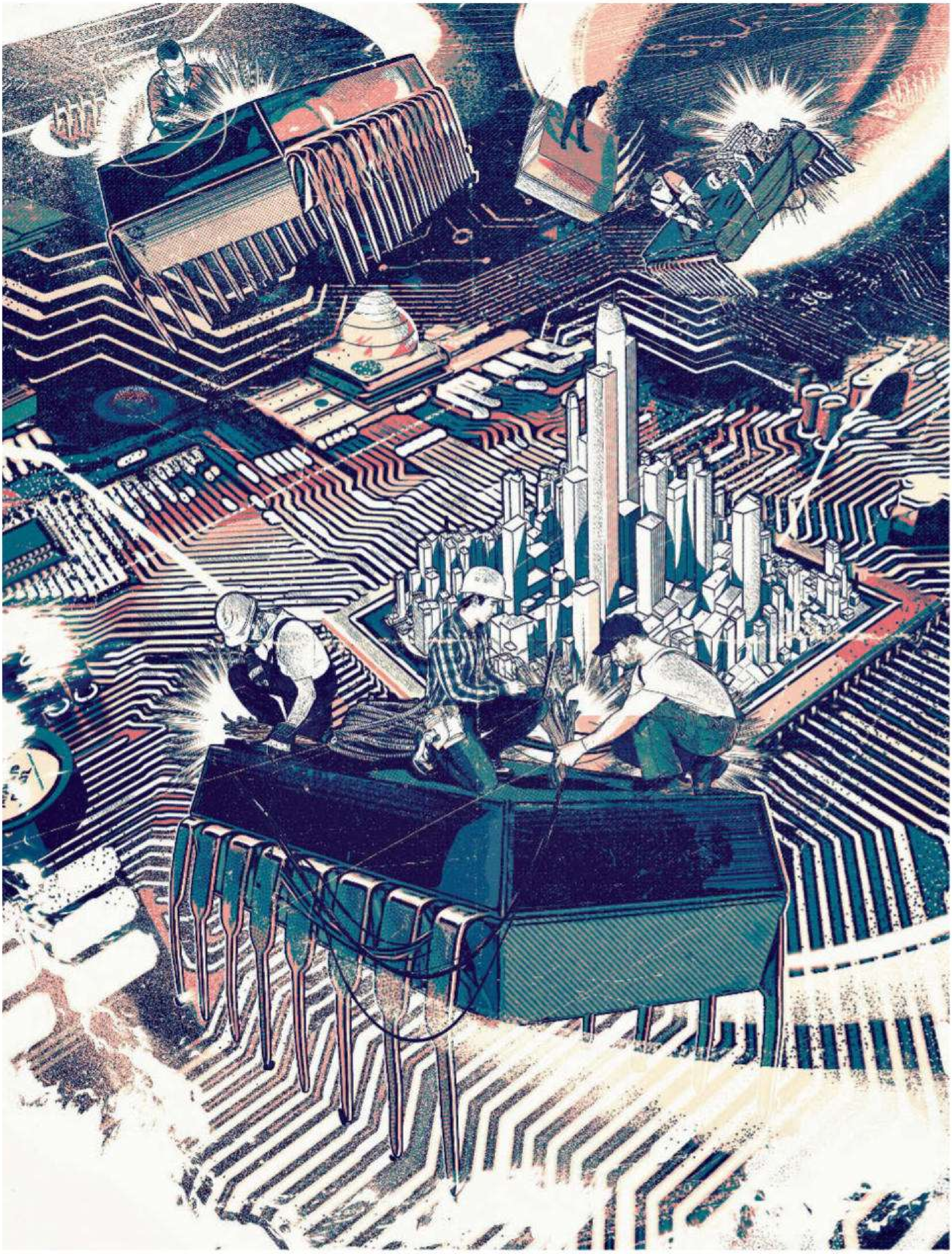


CHRIS MALBON

INTERNATIONAL CHIP WARS

The position of chips at the centre of all computing hardware makes them an ideal place to insert "backdoors" or security flaws that might potentially allow unfriendly powers to spy on what individual computers are doing – and beyond, in a networked world. "For all we know, anything built out of China has 1-800-CALL-CHINA [written into it]," says Cecil Macgregor at data storage company Seagate.

That is a conspiracy theory, he says – but equally we just don't know. With threats of a trade war between the US and China bubbling away, companies are already making choices about which chip architecture to use based on the nationality of the chip company. "If I were a superpower, why would I let some other superpower control me?" says Macgregor.

China is working on building up its own chip design capabilities, but for now its burgeoning technology sector still relies on licensing deals with US chip companies. US chip firm Xilinx has already had to suspend some sales to Chinese consumer electronics company Huawei after then-US president Donald Trump put Huawei on a trade blacklist over national security fears.

It cuts both ways. In 1990, the US made over a third of the world's chips, but that is now down to 12 per cent, with most chip manufacture outsourced to plants in Asia. The US is now getting the Taiwan Semiconductor Manufacturing Company to build a $12 billion chip factory on its own shores, with US president Joe Biden expressing his desire for boosting domestic manufacturing capacity.

all, a complex and specialised business. That has become even more true as we have begun to reach fundamental limits on the tiny size of transistors – the current standard is just 5 nanometres across – and so how many can be crammed on a single chip. A standard central processing unit, or CPU, now consists of multiple "cores", individual chips-on-a-chip that can work in parallel. Algorithms such as the artificial intelligence that underlies our phone's virtual assistant, say, or those that do the high-speed 3D physics calculations that render computer game graphics realistic, increasingly require chips specially optimised to run the relevant instructions more quickly.

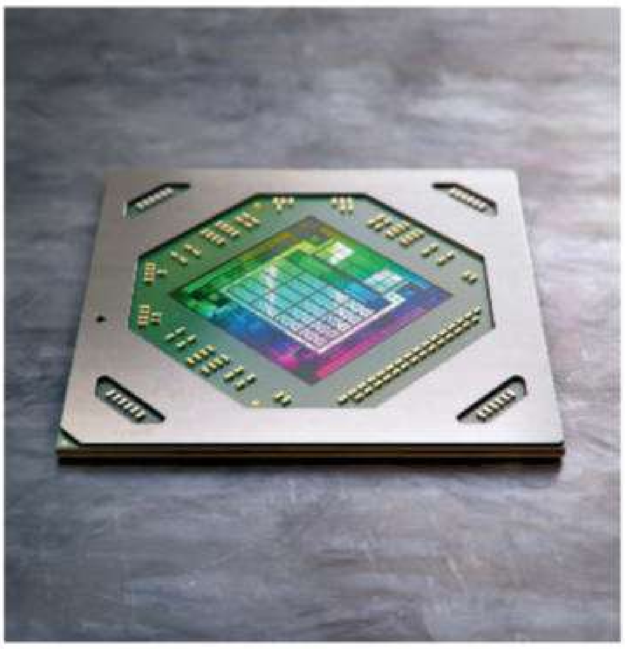
> **"As chips get more complex, security is becoming a hot potato"**

The proprietary model gives stability and certainty to companies building hardware around a given chip, but it can also hamper their ability to innovate. "How much memory can you attach to a single core? Intel decides," says Sivaram. "If you want to add more memory, they say 'buy another core'. It's like 'do you want a new bathroom? Buy a new house'." He says that his company buys tens of millions of chips a year, but still can't get exactly what it needs.

ARM works slightly differently: it designs its cores, but licenses various basic "flavours" of them to end users to manufacture as they see fit. Seagate transitioned to this model just over 20 years ago. This gave more flexibility, says Macgregor, but did little for customisation: the company still had to pick from a handful of pre-determined options. "They're also in it to make money, right? So they have to decide which flavour makes sense for the world," he says. "They want to make sure a lot of people are going to buy it." A very big company like Apple can get around this: it is currently moving from Intel to ARM chips, but has paid extra and used its enormous sway to create its own processor, called M1.

ARM's proposed acquisition by Nvidia, a US company that designs graphics processing units (GPUs) and chips for smartphones, tablets and car navigation and entertainment systems as well as making games consoles itself, has also caused some unease. "If you were a competitor to Nvdia, you would be thinking hard because your core comes from them," says Macgregor. When contacted by *New Scientist*, an Nvidia spokesperson said all customers will be able to continue licensing ARM intellectual property, just as they can today. The UK government is seemingly unconvinced, with recent reports suggesting it has explored the option of vetoing the takeover on anti-competition or national security grounds.

As chips get more complex, security and reliability are becoming hotter potatoes, too. Testing chips currently means either randomly probing one to find flaws, or trying to formally test every possible input and output. The first approach can easily miss problems, and the second quickly becomes unfeasible for all but the simplest designs. Intel recalled around a million Pentium P5 processors in 1995 after a flaw was discovered that could cause certain calculations to be done improperly. In 2011, a flaw in its Sandy Bridge chips cost an estimated $1 billion to rectify. Neither of these came close to two flaws identified in 2018, Meltdown and Spectre, that affected a whole generation of chips from a range of makers. Even Apple's brand new M1 chip has been shown to have an unintentional design flaw, thought to be largely harmless, that allows two programs



ARM

Microchips are at the heart of many devices

that should be strictly separated to share data.

Add to this mix the geopolitical tensions between the two biggest national players in the chip business, the US and China (see “International chip wars”, left), and you can begin to see why some manufacturers are itching for a different way of working. Many now think they see it.

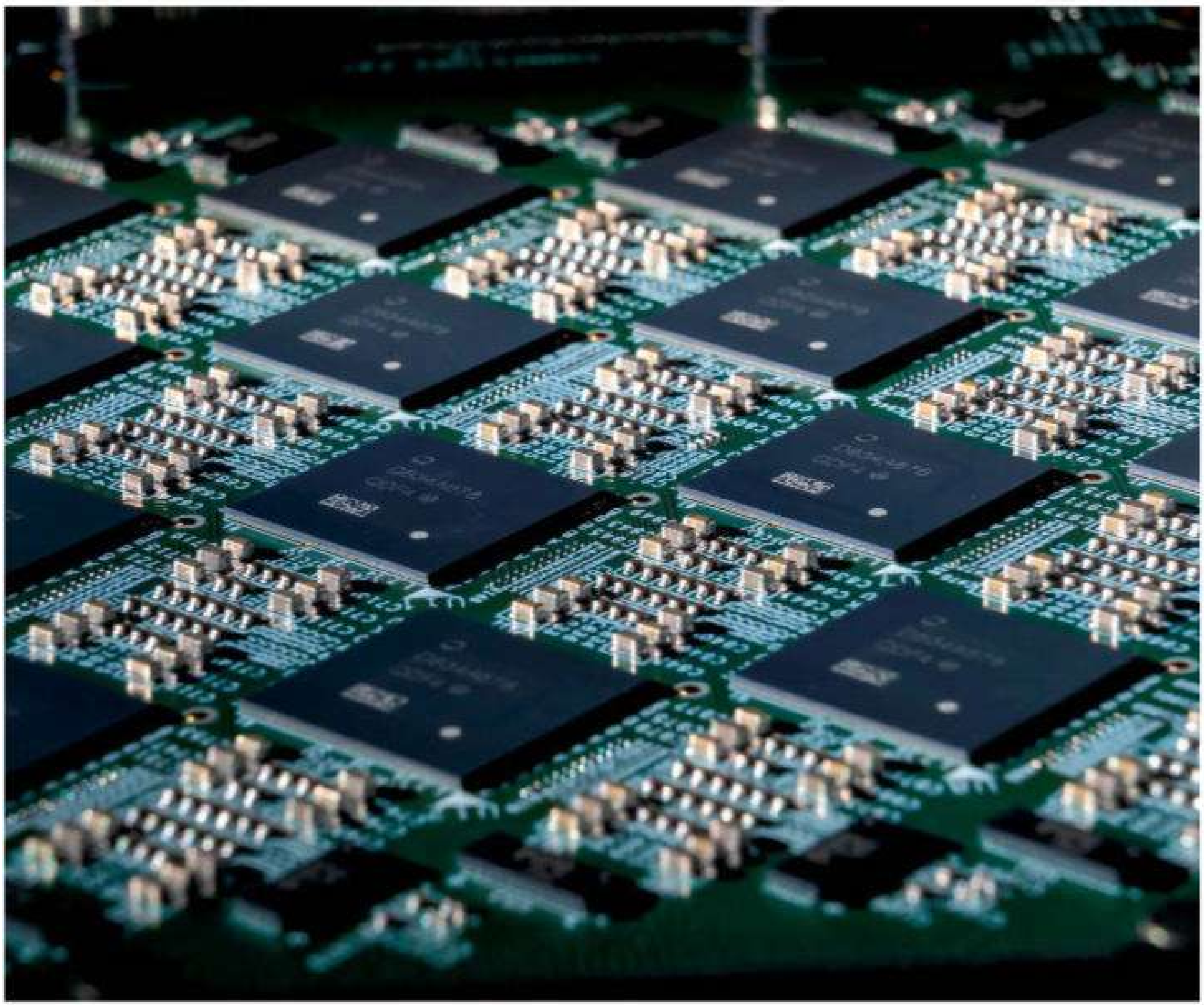
Called RISC, for “reduced instruction set computer”, its origins lie in an academic project that started in the 1980s at the University of California, Berkeley. The original idea was that chips could be made leaner and simpler by having an instruction set with just a few instructions, rather than a vast library to cover every specific, esoteric task. A perennial roadblock to progress was the difficulty of getting to grips with companies’ secret, proprietary designs, so in 2010 RISC researchers set about creating their own chip and instruction set as an educational tool. They called it RISC-V, as it was the fifth RISC research project that co-creator David Patterson had worked on. As students who had learned their stuff on RISC-V chips moved on, the design started to crop up in real-world applications.

In 2015, the specification was spun out with a non-profit company, RISC-V International, overseeing its development. Its big plus is that it is open-source, applying a model that is increasingly a standard in software development. The Linux open-source operating system, notably, has become the basis of the Google-sponsored Android, the most popular smartphone operating system worldwide. It also powers more than half of the world’s most powerful supercomputers.

Open season

The open-source approach allows whole communities of developers to constantly optimise the RISC-V standard, ensuring it works as it should do without any nasty security flaws or backdoors. “The best thing I can do is to be open-source,” says Sivaram. “Let a million people out there try to find a bug in my code.” The rationale for all design decisions is publicly documented, and any individuals or company can participate in development – and repurpose it for their own products for free. “You could make all sorts of flavours, you can add little tweaks to it,” says Macgregor.

The attraction for device manufacturers is clear: creating cheaper products with lower licensing overheads, using chips designed specifically for the task at hand, potentially meaning better performance and battery life. Some companies are already biting. Seagate is one, although it stresses that it hasn’t officially announced any product containing RISC-V chips. Macgregor won’t say what the company is using the standard for, only that customising chips offers advantages over competitors.


TIM HERMAN/INTEL CORPORATION

The chip-manufacturing landscape is changing

Others are less coy. Western Digital has now “fully subscribed” to RISC-V, says Sivaram. A RISC-V chip designed to have a particular functionality will be slightly smaller and give better performance for less power than an off-the-peg chip because it “doesn’t have legacy baggage to drag along with it”, he says. Back in 2016, Nvidia announced it would use RISC-V in its GPUs. When contacted for this article, it confirmed that it now does this, despite its plan to take over ARM.

Sivaram thinks these developments are only the beginning. “I’m not saying it is going to be instantaneous, but it’s only a matter of time before semiconductor cores are going to be open-sourced everywhere. When you buy your Ford or Toyota car, do you know who makes the engine?”

Patterson agrees. “People have this religious fervour about openness. They like this idea and want to make it happen,” he says. “I think RISC-V is inevitable and it’s going to be a lingua franca that’s going to get used from tiny computers to large computers.”

“Because it’s an open-source licence, no one company, country or other entity controls it. Once it’s given out to the community, you can’t pull it back,” says Calista Redmond at RISC-V International foundation. The foundation announced in 2019 that it was moving its headquarters to Switzerland from the US to assuage fears from some of its members, unnamed but thought to be from China, that any one country could wrest control.

Certainly many Chinese companies are in the foundation’s list of partners. After US sanctions by the Trump administration, the ›

HOW CHIPS WORK

A laptop or smartphone chip isn't capable of directly understanding what all your various keyboard strokes, mouse clicks or finger swipes in an app mean. It is up to the high-level software and the operating system to translate those inputs down through layers of abstraction into a language the chip understands. One mouse movement may spark thousands of individual calculations to be run by several different chips inside your device.

A chip's instruction set is the atomic level of all this. It is a framework of all the commands that a processor can carry out. One instruction in the set might be to bring a bit of data out of memory, another to store it again; one will add two values, another will subtract them. What a processor ultimately processes is a string of these instructions.

Today's computers are built of layers of complexity. In the average laptop or smartphone, for example, millions or billions of instructions are executed by a variety of chips to run the operating system and software that you use.

Chinese retail giant Alibaba developed a 16-core RISC-V chip called XT910 that it says could be used for AI or self-driving cars. India, too, has officially endorsed the RISC-V architecture for defence and infrastructure projects, citing a desire to know what is inside chips used to build critical systems. The EU has chosen RISC-V as the basis for a new supercomputer it is building to handle a range of scientific and data processing jobs. Semico Research has estimated that there will be more than 60 billion RISC-V cores shipping in 2025. That compares with 6.7 billion chips using ARM technology that were built in the final quarter of 2020.

Redmond says "legacy" companies like AMD, Intel and ARM should be worried. "We're accelerating the path that took them decades to build," she says. "A lot of big folks are in the tent, and they're deepening their investment."

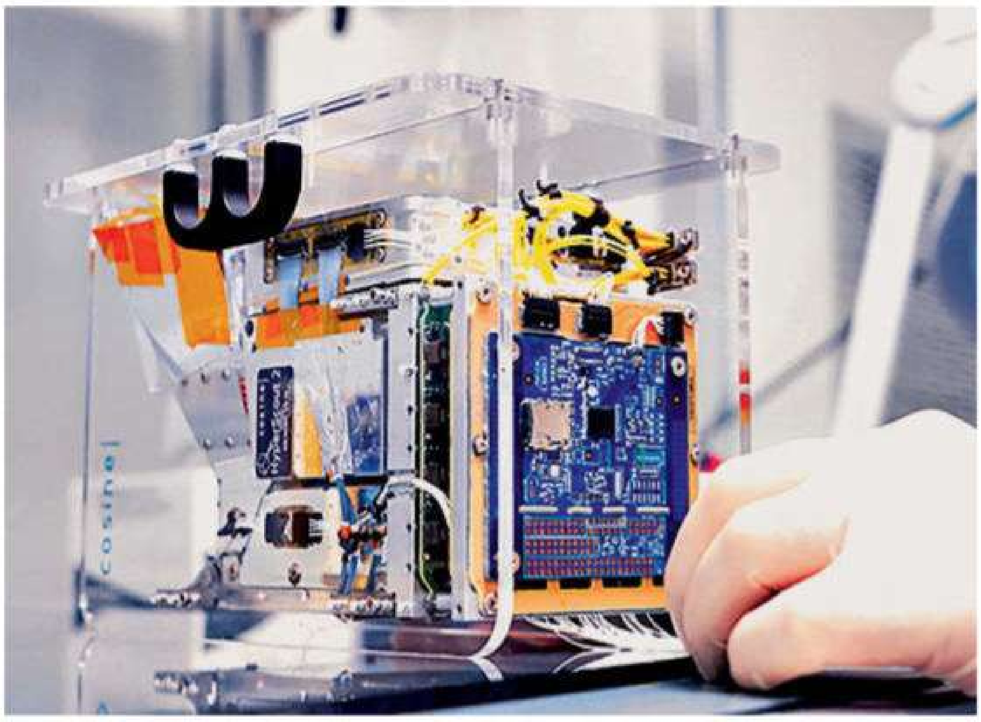
ARM's chief architect, Richard Grisenthwaite, is less sure, despite its putative new owner's involvement. Developing an instruction set is the relatively easy bit, he says; what is hard is creating the ecosystem of supporting tools to help develop chips on that platform. This has to be done from scratch for a new instruction set. "An instruction set lives or dies on the ecosystem, and to make that from scratch, rather than going for ARM, seems tricky," says Grisenthwaite. "It took us 30 years to build momentum. Anyone who wants to go through that same experience that ARM has been through needs to put in the same sort of level of work."

Another problem is keeping focus. The established players can control their instruction sets and approve changes, but an open-source design can be adapted and fork down different roads. Any fundamental divide that opens up could reduce its chances of success – or just create a new monopoly player. Android might be open-source, for example, but its main effect has been cementing Google's commercial position.

> **"Observers say companies like AMD, Intel and ARM should be worried"**

Whether manufacturers will ever be able to entirely wean themselves off legacy technology is less certain, too. For many, there is a need to retain backward-compatibility with older products and that may mean maintaining ARM or Intel chips in their devices. Modern devices already contain dozens of chips using different architectures and that is unlikely to change. And whoever designs chips, licenses them or orders them, the chip makers will still have to churn out the actual silicon. For the next few years at least – until new factories can be brought online – that will be the bottleneck.

In that sense, the RISC-V revolution, if it comes, is likely to go unnoticed by the end user. But if it allows hardware designers to make devices that are a little cheaper, a bit more specialised, a fraction more efficient, then we will all benefit. The chips will go on humming away, doing what we have become accustomed to them doing – silently enabling our digital lives, but perhaps just a little more openly. ▮



An Intel chip on a satellite with onboard artificial intelligence

TIM HERMAN/INTEL CORPORATION

Mathew Sparkes is a technology reporter at *New Scientist*

JENNIE EDWARDS

“Intuition is the lifeblood of a great physicist”

To solve the biggest mysteries in physics, we need to embrace bold ideas and people from a wide range of backgrounds, cosmologist **Stephon Alexander** tells Thomas Lewton

AS A child, Stephon Alexander was awestruck by the broken-down, graffiti-covered train carriages in the depot opposite where he waited for the yellow school bus each morning. Graffiti artists were his heroes, as were urban philosophers. Later, he joined a hip-hop group. “I used to beatbox in rap battles. They called it dropping science too,” he says.

Growing up in the Bronx in New York City in the 1980s might not be the typical training for a theoretical physicist, but it helped shape Alexander’s distinct style. “That collision of all these different cultures was valued because we saw the product,” he says. Alexander learned to embrace the discomfort of difference and saw the ideas that sprung from it. But as a young Black scientist, he was snubbed by colleagues. His speculative ideas were deemed outlandish by some of his peers.

Alexander sought refuge in jazz clubs, cafes and Zen Buddhist centres. Making friends with biologists, musicians and artists, he forged his own approach to the big questions about the nature of reality – one that valued diverse viewpoints, intuition and imagination.

Today, Alexander is a cosmologist, string theorist and jazz musician. He heads a research lab at Brown University in Providence, Rhode Island, seeking to unite the smallest and largest entities in the cosmos and unearth what came before the big bang. He is also president of the National Society of Black Physicists.

In his new book, *Fear of a Black Universe: An outsider’s guide to the future of physics*, Alexander argues that welcoming new voices into the “club of physics” will be essential to breaking new ground. Scientists could learn a lot from graffiti artists, once regarded as vandals but now revered by the art establishment, he says. “They recognise that it’s important to keep a foot on the outside and to keep on talking to others. It’s at that interface that we can expect new innovations to come,” he says. In this way, he hopes off-road thinking can put physicists back on the right track.

Thomas Lewton: Alongside theoretical physicist Lee Smolin, virtual reality pioneer Jaron Lanier and others, you recently proposed that the ›

universe learned its own laws in the same way that artificially intelligent neural networks teach themselves. What is the appeal of a self-learning universe?
Stephon Alexander: I've asked the why question throughout my career: why is our universe special? String theory tells us something about how the laws of nature emerge. You start out with a string – there's no gravity or particle physics – but then these forms and forces appear. But string theory doesn't answer the why question. It lacks a mechanism to select which of the slot machine of 10^{500} possible universes is our universe.

If the forces in our universe were slightly different, then stars wouldn't be able to burn hydrogen. You couldn't make carbon, and if you can't make carbon, then where are we? Why are the laws as we see them today? So we're trying to come at this another way. A self-learning universe provides a mechanism to select those laws.

How could the universe be self-learning?
Learning is accumulating information and then making decisions based on this. It also needs some kind of stability; it must build and be sustained through time. So you start off with a set of very simple primordial rules, which are also a set of learning rules. These are prior to the laws of nature. If the rules can learn some of the laws we now know exist, like the laws of gravity, that's a good learning system.

We have the universe of learning architectures and machine learning and artificial intelligence. And then, in the other universe, we have the laws of physics as we know them. It's two sides of the same coin.

Which fundamental laws might have a learning architecture built in?
"Matrix models" are one example. You can picture these as chequerboards with different colours in each square that are constantly changing. Each matrix can have billions of columns and rows. Let's assume this matrix theory is the mother of all theories, that it contains all possible laws. How does it realise the specific laws necessary for our world?

The mathematics of matrix theory seems to have some of the ingredients of a particular type of neural network. The idea then is to show that at least one of these neural network architectures can learn one of those laws. That correspondence would be an indicator. That's what's wild and beautiful about this idea, because if that's nature at its most fundamental, then nature itself is like a neural network.

Wouldn't it be a leap to go from this correspondence between the laws of physics, matrix theory and neural networks to then saying that the universe actually is a neural network?
It is a leap. It would be analogous to a neural network. We're still playing with the idea, and it might end up taking us in another direction.

It also wouldn't necessarily mean a neural network in the sense of a hardwired computer. A computer is just the substrate for neural networks. There could be something more biological going on. The universe itself produced brains, so why couldn't the universe itself be a superbrain?

If you find enough of these correspondences, would we have to consider neural networks to be as "real" as physical laws?
I think we would have to. It would be real in the same way that we think electric or magnetic fields are real. Or think about when Paul Dirac predicted antimatter. You have a mathematical equation that seems to say something absurd about reality – that antimatter exists – and it then turned out to be a hidden part of reality.

How does a self-learning universe differ from an evolving universe?
Evolution depends on the idea of fitness within an environment. In evolution, species get killed off. In the same way, an evolving universe depends on there being a large population of universes and only the fittest ones – say with the right constants of nature – will survive.

Learning means that you have an opportunity to make a mistake without getting wiped out. These matrix models have a lot of space in which to store information. So you store that mistake as a memory and keep moving forward. It's akin to jazz improvisation.

> "The universe produced brains, so why couldn't the universe itself be a superbrain?"

Why are bold ideas like this such an important part of doing physics?
I'm this kind of physicist who thinks these wild ideas. I even have ideas that I'm afraid to tell for fear of not being taking seriously or respected as a physicist. It certainly doesn't help that I'm Black, and the biases and presumptions that go with that.

I went into this book asking: why do I do physics this way? Then I realised Max Planck thought consciousness subsumes everything. That Niels Bohr was studying Confucianism and Taoism. Then, wait a minute: Wolfgang Pauli was doing dream analysis?

It's good for the advance of science. History has proven that to be the case. You need it all, because we're dealing with the unknown. We're dealing with nature that's much smarter than we could ever be.

In your new book, *Fear of a Black Universe*, you write about the "club of physics". What is that?
We form groups, we form social bonds, and I don't think scientists are devoid or excused from that. These bonds are surrounded by certain social forces that can penalise or benefit you. It's a very human thing.

There's also an intellectual confidence and arrogance that makes physics hard for some people. We live in a Western society where people of colour and women have been stereotyped to be lazy or emotional or less intellectually endowed. I have my own personal experience of it. This is not saying: "Oh, give me a pass, because I'm suffering." It's actually the exact opposite. If you're not fitting in, you've got to work hard.

Who introduced you to physics?
My high-school teacher Mr Kaplan told me that "intuition is the lifeblood of a great physicist". It's Einstein's thought experiments, it's Schrodinger's cat. We intuit first, then confirm with math.

In my first physics lesson with Mr Kaplan, I didn't know a damn thing about physics. But from watching him throw a ball up and down, I intuited the conservation of energy. That opened up my eyes that I could do physics. You don't have to be some genius. It's a human thing, it's our birthright.

STOCKSTORE/SHUTTERSTOCK

Physicists can learn from graffiti artists, says Alexander

A revolution in theoretical physics – akin to the discovery of general relativity or quantum mechanics – seems long overdue. Do you attribute this to an unwillingness to embrace people from a variety of backgrounds?
I'm going to put my sword in the ground and say yes. I'm not saying we should just bring everyone in and [sing] *Kumbaya*. But we should look into this and empower those who are doing good work.

Given how deeply mathematical theoretical physics has become, do you think that makes it harder to apply intuitive thinking?
It does make it harder, but that's why these things should be done collaboratively. Some people might play the role of being speculative while the others are more grounded. By the way, that's what happens in jazz improvisation. When you're improvising your solo, you're exploring, but it's kind of weird if there's no background band supporting that. Then everyone else takes their turn to solo. We need both the grounding and the exploration.

How do you improvise when doing physics?
My intellectual training has not just been learning mathematics and the concepts of physics, but also learning philosophy.

You still need those mathematical tools. You need to find yourself within the tradition of physics. I believe in experiments. But you also need to explore wild ideas and be brave. You need to talk to others who you've been taught not to respect. They might have something to teach you.

I've had the fortune to train with Zen masters. I also trained in dream analysis with [theoretical physicist] Chris Isham. That's where a lot of the magic started to happen. It's like the Zen proverb of emptying your cup. How do you empty your mind so that it can contain new ideas? Ideas are going to come from irrational, illogical places sometimes.

"Koans" are these Buddhist riddles and paradoxes that are thrown at you. My entire life, as a physicist, I've trained my mind to be mathematical and to think logically. But you can't get insight into these koans with that kind of thinking. It's before thinking. The creativity in physics also lives in that place. For many years, I didn't talk about any of this.

So what initially seems implausible can actually turn out to be what reality is deep down?
Absolutely. Take quantum mechanics: a particle can be a wave and a particle. But our experiences of waves and particles seemed to be separate. It's an impossibility that then became a reality. Or look at the new interface between consciousness, physics and artificial intelligence. Scientists are writing papers about it. We're now embracing what was once thought to be absurd.

In your book, you write about how Bantu-Kongo philosophies have led you to new ideas about quantum cosmology.
I was talking about my craft with the legendary bassist Melvin Gibbs, and afterwards he sent me a book about African cosmology. I realised that some elements of the origin story of the Bantu-Kongo people of West Africa fit very nicely into a problem in quantum cosmology.

Quantum cosmology is about applying the laws of quantum mechanics to the entire universe. Stephen Hawking and James Hartle came up with this idea of the wave function of the entire universe: that the entire universe is a quantum-mechanical system containing the potential of all things.

If you accept this, then you have to deal with the measurement problem. If there are no observers out there to measure the wave function of the universe and so collapse it, what do you do about that? The idea is that the universe observes itself. But how does it observe itself? Well, if there's some form of protoconsciousness associated with this wave function, then that observer doesn't have to be at a specific point in space. The observer is non-local. But through that observation, the universe disintegrates into local observers.

This is a Bantu-Kongo idea called mbungi. In the state of mbungi, both physical and conscious awareness are complementary. They are a duality – just like wave-particle duality in quantum mechanics, where a particle is a localised version of a non-local wave.

How can physics welcome people from a wide range of backgrounds while still embracing their differences?
I've created a group for young Black theoretical physicists and scientists called NeXus. There are still so few Black theoretical physicists. In my time, when I was a postdoc, there was only me and somebody else around the globe.

The idea is, everybody is a different kind of theorist. We have researchers in quantum gravity and machine learning, we have black hole physicists and theoretical biologists. They meet to share techniques and to do research projects together. And when they meet, they're all thrown out of their comfort zones.

We need to embrace discomfort. If you are hiking up a mountain and you are uncomfortable, are you just going to hike back down? If you hear a different way of thinking about something, what are you afraid of? That's *Fear of a Black Universe*. ▮

Thomas Lewton is a freelance writer based in London

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The back pages

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Life-sapping hot dogs and rocketeering billionaires p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Science of gardening

Can you not dig it?

From novices to hard-core allotmenteers, all gardeners could benefit from the "no dig" method, says **Clare Wilson**

Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Cardboard
Compost
Arbuscular mycorrhizal fungi spores
Home-made plant compost

Science of gardening appears every four weeks

Next week

Citizen science

OF ALL my garden tools, the one I have used most must be my trusty spade, a lovely small and light one with a comfortable wooden handle. But recently, it has been getting less action because I have been stepping up on the "no-dig" approach to gardening.

All gardeners need to dig sometimes, of course, such as when making holes to put plants in or rooting out weeds. Traditional advice is that we should also turn over all the soil every autumn, to aerate it, improve drainage and mix in soil improvers like manure.

For the past few years, though, I have been increasingly embracing the no-dig approach. On the allotment, I suppress weeds on bare ground over winter by covering the earth to block out light as much as possible.

I used to do this using plastic sheets weighed down with bricks. This year, I have started adopting the system of no-dig advocate Charles Dowding, a UK market gardener and writer. You put down flattened cardboard boxes and cover with some kind of mulch, such as manure or home-made compost. As the cardboard rots, worms take the organic matter down into the soil.

This approach may also be better for the soil. Most plants get help in absorbing water and nutrients from a fine network of thread-like fungi on their roots. A large component of these fungal threads is a sticky protein called glomalin, discovered in 1996. Together, the threads and released glomulin make soil clump into bigger particles.

SJ IMAGES/ALAMY

If soil is dug over, it breaks up the particles and exposes organic material they contain to decomposition by microbes, releasing carbon dioxide. Soil with larger particles retains more moisture and is less prone to nutrients leaching away.

A recent trial in farmers' fields shows that "no-till" boosts soil glomalin and is also likely to reduce soil erosion. On a smaller scale, Dowding says trials in his market garden show no-dig plots give slightly higher yields of fruit and vegetables – as well as being less work of course.

When it comes to garden borders, cardboard coverings may be impractical but there are other ways to boost soil glomalin. You can add the fungi to your soil, either by buying packets of arbuscular mycorrhizal spores or adding home-made compost, a natural source.

Dowding also questions the standard advice for planting new shrubs or trees, for instance, which is to dig a hole two or three times wider than the root ball and loosen the surrounding soil to help the roots penetrate. "It's a myth this is needed," he says.

Instead, we can just dig a hole the width of the root ball to avoid disturbing the soil more than necessary. I can personally vouch the new approach is easier on the back. ▮

These articles are posted each week at newscientist.com/maker

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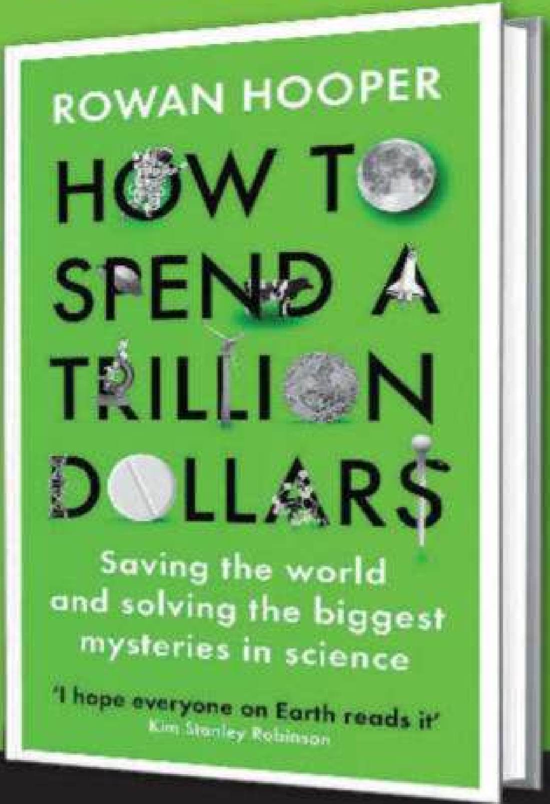
Rowan Hooper doesn't have a trillion dollars – but if he did...

'Original and ingenious... I hope it sells a trillion.'

PHILIP PULLMAN


ROWAN HOOPER
HOW TO SPEND A TRILLION DOLLARS
Saving the world and solving the biggest mysteries in science
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P
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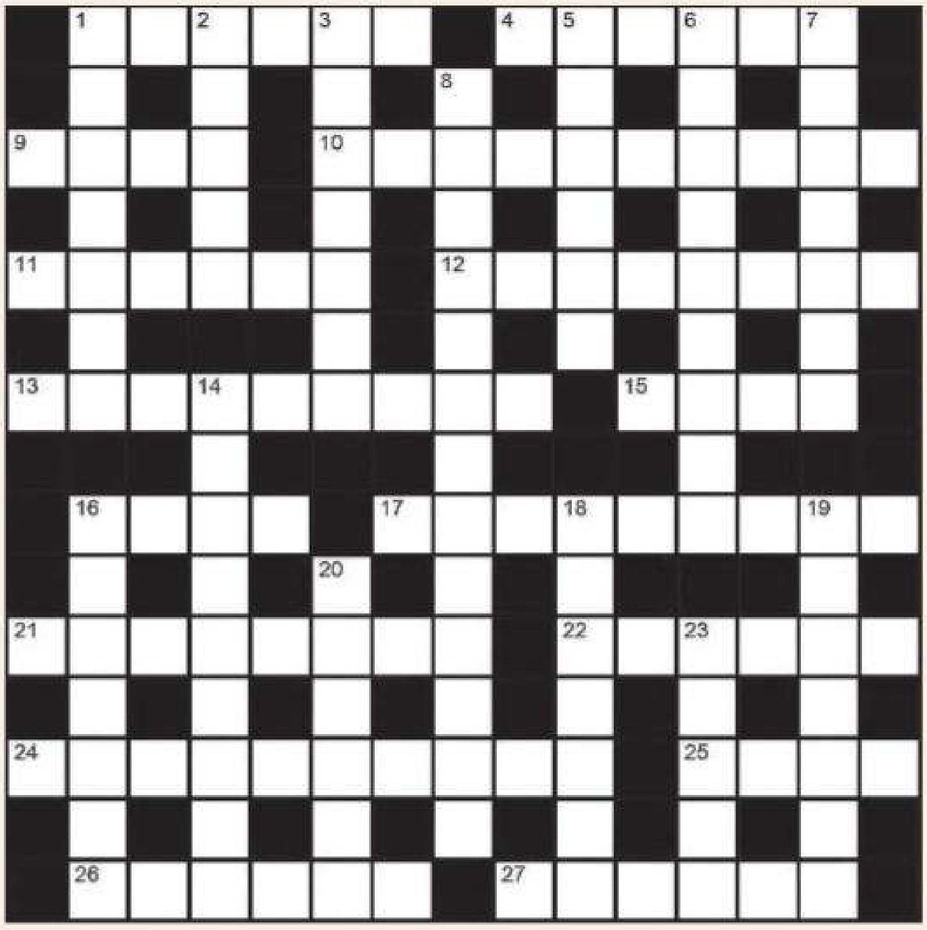
Quick crossword #91 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Edward ___, creator of the smallpox vaccine (6)
4 Lizard of Central and South America (6)
9 Ova (4)
10 Data discipline (10)
11 Speech delay (6)
12 Outer part of the auricle (8)
13 Arboreal mammal of Africa (4,5)
15 Humphry ___, scientist who isolated sodium in 1807 (4)
16 Profound; low-pitched (4)
17 Function of certain muscles (9)
21 ___ plate, part of the lithosphere (8)
22 Most common naturally occurring form of iodine (6)
24 Structural threads of around 1 billionth of a metre (4-6)
25 Therefore (4)
26 Lymphocytes that mature in the thymus gland (1-5)
27 Reproductive organ of a flower (6)

DOWN

1 ___ veins, major blood vessels in the neck (7)
2 Of the nose (5)
3 MDMA (7)
5 Swelling caused by an enlarged thyroid (6)
6 Space explorer (9)
7 Proto-scientific discipline (7)
8 Darkened room with a projecting lens (6,7)
14 Anode or cathode (9)
16 Made from moulded metal (3-4)
18 Singleton, in mathematics (4,3)
19 Eight-sided figure (7)
20 Reuse of urban land (6)
23 REM experience (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #118

1 What is a mutual, symbiotic association between a fungus and a plant called?

2 Which constellation is known for its distinctive "W" shape?

3 How many chemical elements are named after people?

4 What is the principle energy-carrying molecule in cells?

5 Which of these points isn't found in the Mariana trench: Challenger Deep, Horizon Deep or Sirena Deep?

Answers on page 55

Puzzle

set by Barry R. Clarke

#130 Arithmagic

```
  2 8 1 9
+ 3 4 5 6
  -------
  6 2 7 5
- 2 3 4 9
  -------
  3 9 2 6
```

Deep in the jungle, the explorer Dr Quiverbone has chanced on a civilisation that has invented its own deletion arithmetic. In the example shown above, the first two rows added together give the third, while the fourth subtracted from the third produces the fifth.

The idea is to delete one digit from each row and close the gaps left behind to leave three columns of digits that still form a correct sum. Then repeat the process, erasing a second digit from each row to leave two columns, and finally a third to leave one column, closing the gaps to leave a correct sum after each deletion as before.

Which numbers should be deleted and in what order?

Solution next week

Seeing the light

A rainbow is formed from a continuous spectrum of wavelengths of light, so why do we perceive it as seven separate bands of colour?

Matt Chamings
Barnstaple, Devon, UK
Our perception of a rainbow is coloured (pun intended) by our expectation that there are seven colours. In reality, there aren't seven distinct bands, but multiple colours blending and shading into one another.

Robert Senior
Uppingham, Rutland, UK
Around 1665, Isaac Newton performed experiments with a prism producing a spectrum in which he identified seven colours.

Prior to that, the spectrum had been thought to have five colours. For example, in his book *Experiments and Considerations Touching Colours*, Robert Boyle described the spectrum he produced with a prism as "denoting the five consecutions of colours Red, Yellow, Green, Blew, and Purple".

> **"Our perception of a rainbow is coloured by our expectations. In reality, there aren't seven distinct bands of colours"**

This book was published in 1664, just before Newton started his experiments. However, the number seven had long been considered mystical, denoting perfection and completeness. This sort of mysticism fascinated Newton as much as science, so he thought there must be seven colours in the rainbow. He added orange and split purple into indigo and violet.

I am a volunteer at Woolsthorpe Manor, Newton's family home, and have often demonstrated his prism experiment to visitors. I have never been able to see indigo and violet as separate colours.

SEVENTYFOUR/GETTY IMAGES

Will we one day run out of new combinations of musical notes to create original tunes?

This week's new questions

Changing tune **Will composers run out of new combinations of musical notes to create original melodies? Or are there infinite combinations?** ***Bonita Ely****, Sydney, Australia*

Rookie move **We recently saw a rook stuff three to four pieces of bread in its mouth, fly off and then bury them. Is this normal rook behaviour?** ***Howard Watkins****, Reading, UK*

Mike Follows
Sutton Coldfield, West Midlands, UK
It is said that Isaac Newton only perceived five colours in the rainbow and added two more (orange and indigo) because the number seven had mystical significance. We have seven days of the week, seven natural notes in most Western music and, in Newton's time, only seven planets had been discovered.

While this was simply one of Newton's mystical beliefs – others included alchemy and the philosopher's stone, which could turn base metals into gold – it has become part of our cultural inheritance.

In the UK, we are taught the mnemonic "Richard of York gave battle in vain", so we look for the corresponding colours in the rainbow. Perhaps another culture would have come up with a different number of colours and a different mnemonic.

Luce Gilmore
Cambridge, UK
The retina has cones with three opsin pigments that are sensitive to different colour bands, peaking in orangish-red, green and deep blue. However, in the retina, colour information is encoded into red-versus-green and yellow-versus-blue channels for transmission to the optic cortex. Hence the four basic colours of visual psychology are red, yellow, green and blue.

Cyan looks distinct from blue because both green and blue cones are firing in that band, so it appears brighter. Similarly, orange is towards the yellowish part of the red band where green cones are still firing strongly. Owing to the retinal encoding, the band we perceive as yellow is very narrow, whereas the red band is very broad. Also, violet appears reddish due to that encoding.

Keith Ross
Villembits, France
We only have three colour receptors in our retinas. These respond to red, green and blue light. If two of these receptors are activated at the same time, we see three more colours: yellow (red + green), cyan (green + blue) and magenta (blue + red). These are also used in colour printers, and the last one isn't a rainbow colour. If all three receptors are activated, we "see" white. Our computer and TV screens use the same primary colours as our eyes.

People often get confused by being told at school that the three primary colours are yellow, red and blue. Actually, these artistic colours are, from a physics perspective, the secondary colours of yellow, cyan (an artist's blue) and magenta (an artist's red).

The difference is that your eyes and a TV screen start with no light and you gradually build up to white, whereas your printer starts with white paper and so, as you add ink, you start subtracting colours from the white.

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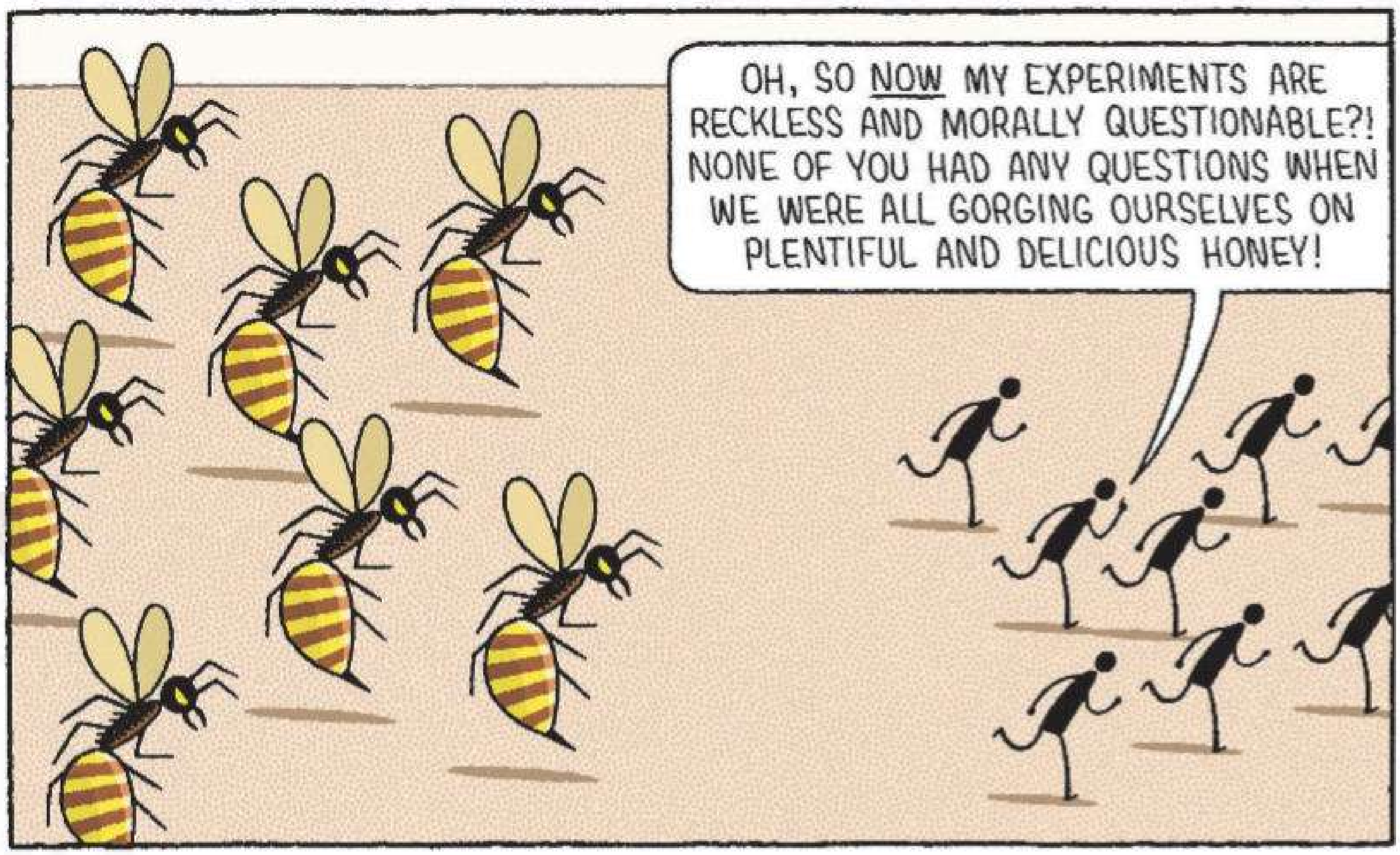
Snail trail

Why do snails sometimes leave dotted trails (pictured right)?

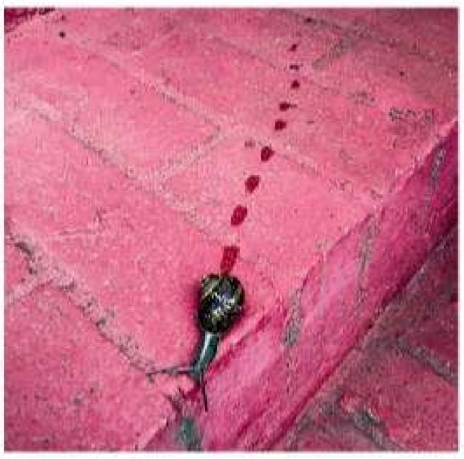
Melissa Price
College of Tropical Agriculture and Human Resources, University of Hawai‘i at Mānoa, US
I haven't seen research done on this specific question before, but I could guess at a few options. Slime

Tom Gauld
for New Scientist


OH, SO NOW MY EXPERIMENTS ARE RECKLESS AND MORALLY QUESTIONABLE?! NONE OF YOU HAD ANY QUESTIONS WHEN WE WERE ALL GORGING OURSELVES ON PLENTIFUL AND DELICIOUS HONEY!

trails are used for communication between snails and may help them return to the same spot to rest for the day or night (a behaviour we see in snail species of *Achatinellinae*, though we have never studied how they know to return to the same spot). It can also help them find potential mates.

Some species, like rosy wolfsnails, use the slime trails of other snail species to track them down and eat them. A dotted trail like this could be a predator-avoidance mechanism, or it could be a way to minimise energy expenditure in manufacturing hormones/pheromones.



> **"Slime trails are used for communication between snails and may help them return to the same spot to rest for the day or night"**

Heike Reise
Senckenberg Museum of Natural History Görlitz, Germany
Snails switch pace when the ground becomes too rough (such as a concrete surface) and would require a lot of creeping slime. By "loping", they slow down a little, but save mucus.

It is unclear which species are capable of that, but quite a few can and clearly *Cornu aspersum* (the type in your photo) and *Helix pomatia* (observed by me) are able to do so.

Peter Fischer
ETH Zurich, Switzerland
Here's a halfway-educated guess. The motion of the snail is basically a wave travelling down the foot muscle: some parts hold firmly to the ground and some push forwards (and have loose contact with the ground).

It could be that the unusual track is caused by a complete detachment of the pushing part of the foot – maybe by a "body-builder" snail with strong muscles.

Rob Thomas
Birmingham, West Midlands, UK
If you had one foot, don't you think you'd hop too?

Roger Miles
St Albans, Hertfordshire, UK
It's simple. The picture shows a snail approaching a cliff edge and braking hard. Its anti-lock braking system has kicked in.

Marina Grayden
via Facebook
Well, I am surprised at all these answers. Of course it's because they actually have tiny legs and two feet. They take big strides when they walk but nobody can see those little, secret footsies and tiny legs because they hide them inside the shell. Just like landing gear on a plane, they can retract. ▮

Answers

Quick quiz #118
Answers

1 A mycorrhiza
2 Cassiopeia
3 Nineteen
4 Adenosine triphosphate (ATP)
5 Horizon Deep. It is the second-deepest point on Earth and is found in the Tonga trench in the Pacific Ocean

---

Cryptic crossword #65 *Answers*

ACROSS 7/10 Havana syndrome, **8** Ethane, **9** Kelp, **11** Head off, **13** Spelt, **15/18** Chaos theory, **17** Cordite, **20** Tamarind, **21** Haem, **22** Strata, **23** Reverb

DOWN 1 Gamete, **2** Warp, **3** Salsify, **4** Veins, **5** Theropod, **6** Animal, **12** Dioramas, **14** Ponders, **16** Hearth, **19** Titan, **21** Hive

---

#129 Dungeons & Diagrams
Solution

There are four rooms with an odd number of doors: C, E, G and H. Since Bernie goes through each door only once, he must start and end in two of those rooms, and the other two must be connected by the secret door (making their total number of doors even). The only crate that joins two of those rooms is the one between C and H, so that must be the secret passage, and you start and end in G and E. Since we know he places the treasure chest next to a table, that must be in room E, so he starts in room G.

Editor's note: *Puzzle 127 Brahms and Liszt had more than one solution. Apologies for any confusion*

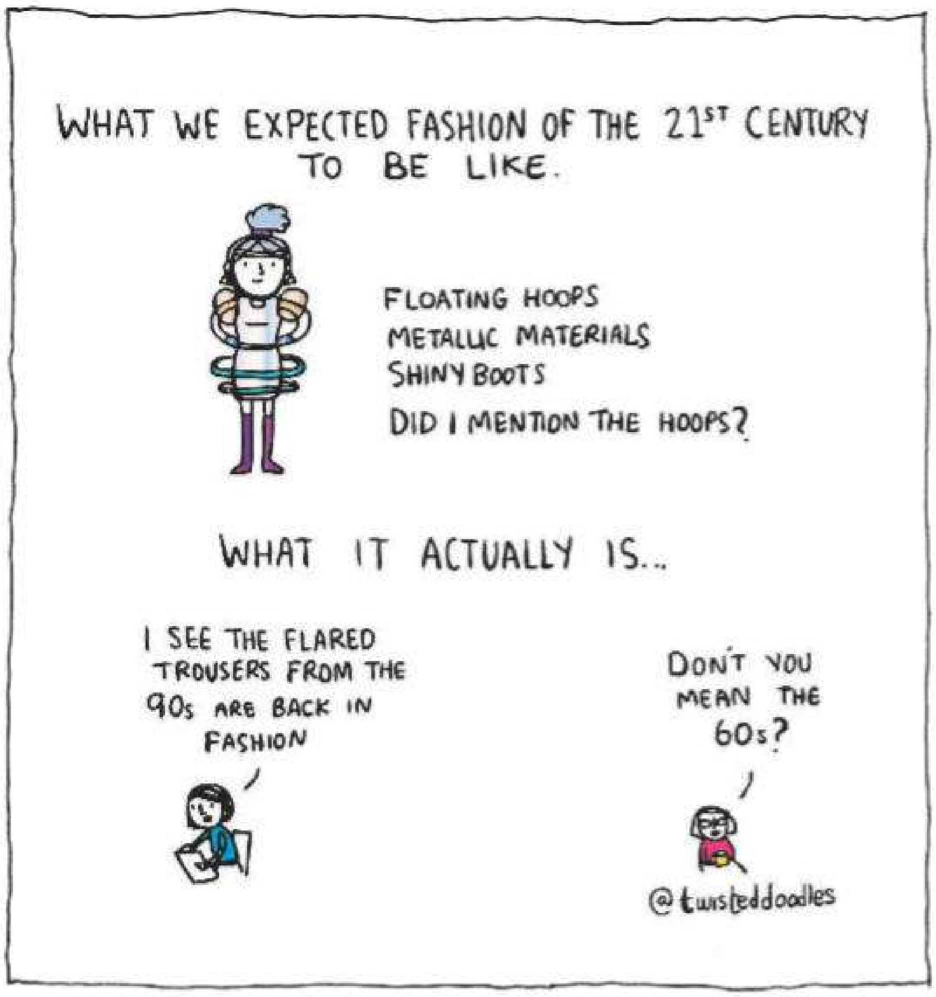
Branson pickle

The world was agog in July as two grown men squared off about who would be the first to reach space on their own rocket. Amazon founder Jeff Bezos looked set to win when he announced his Blue Origin take-off for 20 July – only to see Virgin Galactic founder Richard Branson pip him to the post with an 11 July flight.

That wasn't the end of the cockpit fighting, though. As the Virgin Galactic trip wouldn't be quite high enough to meet the international definition of space flight, Blue Origin cast aspersions on the size of Branson's, ahem, trajectory.

Feedback had to watch coverage of the missions through our fingers, because space flight isn't the kind of endeavour that should be rushed. It wasn't just safety on our mind, but also what Branson might do in front of cameras. He has been known to demonstrate his manliness by picking up the nearest woman and brandishing her aloft like a human trophy, as documented on a blog called "Richard Branson picking up women". We were glad to see he didn't attempt this stunt with his two female fellow crew members.

Twisteddoodles *for New Scientist*


WHAT WE EXPECTED FASHION OF THE 21ST CENTURY TO BE LIKE.
FLOATING HOOPS
METALLIC MATERIALS
SHINY BOOTS
DID I MENTION THE HOOPS?
WHAT IT ACTUALLY IS...
I SEE THE FLARED TROUSERS FROM THE 90s ARE BACK IN FASHION
DON'T YOU MEAN THE 60s?
@twisteddoodles

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Consideration of items sent in the post will be delayed

Hardly rocket science

Thankfully, both missions were successful, but it has emerged that Branson's flight didn't go entirely smoothly. During the ascent, first a yellow warning light came on, to signal that the rocket-plane was going off-course, then a red one, indicating a need to take corrective action or to abort the mission, it has been reported.

While a company spokesperson said the flight was never in danger, anonymous company sources told *The New Yorker* that the safest response would have been to abort. And a Virgin Galactic pilot has previously said such a red light should "scare the crap out of you".

In the meantime, the US Federal Aviation Administration has grounded the company's space flights until the incident has been investigated. The reduction in emissions from keeping the rocket-planes in their hangars is something the planet can be grateful for, if not Branson.

Just a minute

Talking of living dangerously, a colleague sent us a press release from a new flavoured water brand using "retronasal technology" – translation: it smells nice – which claims that every soft drink we consume cuts our lifespan by 12.5 minutes. Can this be true?

Feedback is sceptical. Putting aside the fact that different studies regularly assert that the worst dietary sin is, by turns, sugar, fat, starch, meat or, indeed, any major food group depending on what day of the week it is, the press release has an implausible level of precision over our allotted time on Earth. It seems unlikely that a 20-year-old innocently quaffing a can of cola today is condemning themselves to die, not 60 years hence, but instead in 59 years, 11 months, 29 days, 23 hours and 47.5 minutes. Still, we have come to expect such unscientific pronouncements from press releases.

An apple pie a day...

Except... what's this? A paper in respectable, peer-reviewed journal *Nature Food*, which calculates the same implausibly precise lifespan metric for food items ranging from chicken wings to macaroni cheese. A hot dog, for instance, takes 36 minutes off your life, while apple pie lengthens it by 1.3 minutes.

Sadly, when one of the authors announced their findings on Twitter, the reception was... impertinent. One respondent said that they had eaten so many hot dogs that they should have died 56 years ago, while others used unkind terms such as "pseudoscience", "garbage" and other words that shouldn't be repeated in a family publication.

Taking the results at face value, though, a quick calculation suggests that if you must have a hot dog, just follow it with 27.7 apple pies and there will be no net change. Incidentally, the most life-lengthening food, according to this study, is peanut butter and jam sandwiches, each one making you live half an hour longer. Eat nothing but these and you would presumably live forever – or perhaps it would only feel like that.

Horsing around

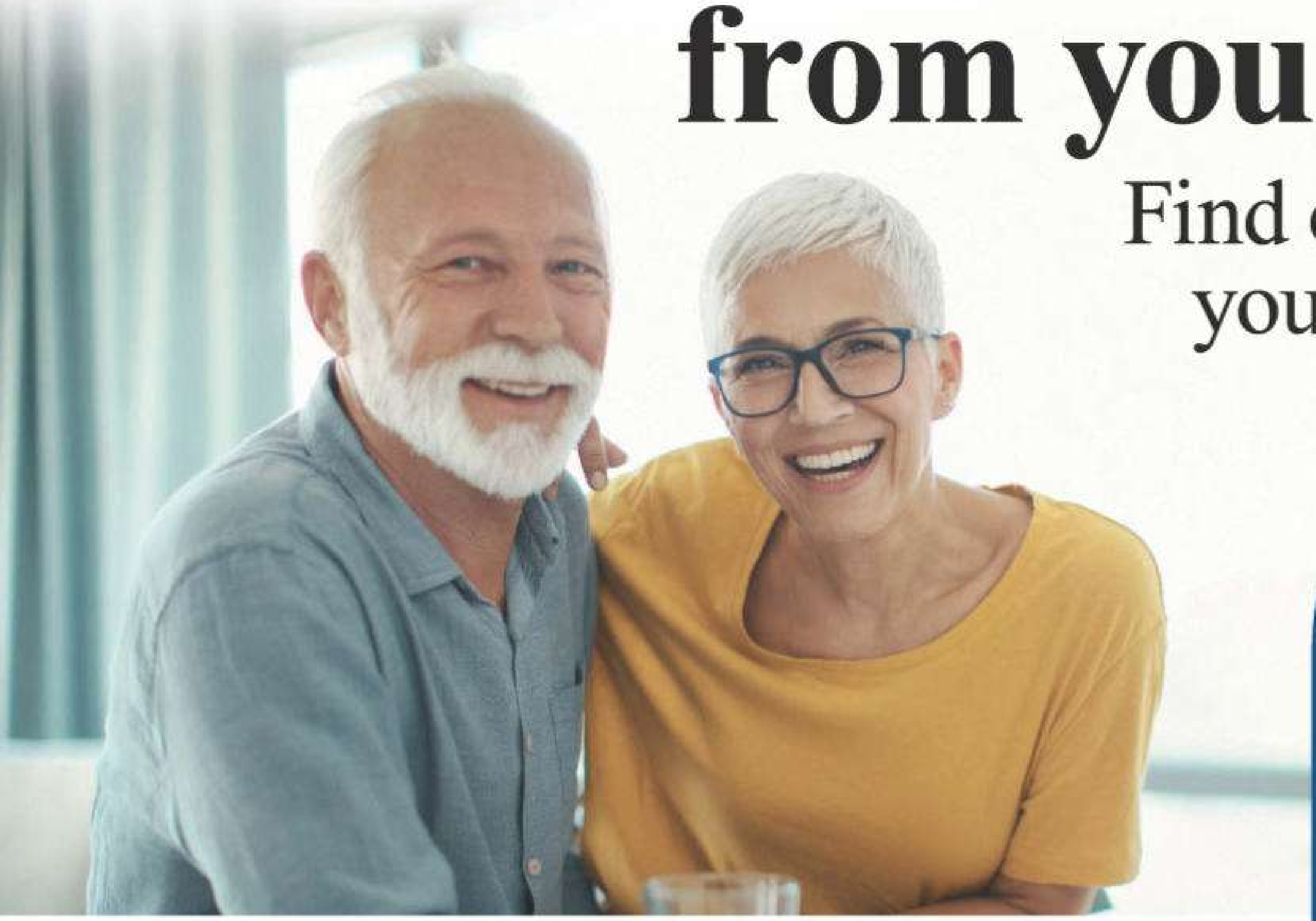
One item not in that paper's catalogue of life-extending substances is ivermectin, the horse dewormer that is a covid-19 wonder drug, according to conspiracy theorists. Judging by their communications on social media, it seems to be the same people who don't trust coronavirus vaccines – tested in tens of thousands in carefully monitored randomised trials – who are placing their faith in a drug that is untested and unlicensed for covid-19.

While ivermectin is used in people to treat parasitic worms and head lice, most doctors won't prescribe it for covid-19, so conspiracy theorists are resorting to buying the veterinary version of the drug. This comes in a more concentrated form, though, so is sadly leading to overdoses, causing vomiting, diarrhoea and seizures.

Veterinary stores are now quizzing prospective ivermectin buyers on their horse breed and insisting on production of a horse selfie. The US Food and Drug Administration has a diplomatically written advice sheet on why it is inadvisable for people to take animal medicines, but whoever runs their Twitter account was more succinct, saying simply: "You are not a horse. You are not a cow. Seriously, y'all. Stop it." Words to live by – literally. ■

Unlock the tax-free cash from your home

Find out how much you could release



GET YOUR FREE EQUITY RELEASE GUIDE

Everything you need to know about releasing tax-free money from your home

From the UK's No.1 Equity Release Advisor

Age Partnership

Request your free copy today and find out more about releasing the money from your home

Whether it's repaying your mortgage so you don't have to worry about making monthly repayments, or just making life more secure for the future, we can help. We have a large team of fully qualified advisors available to speak to you over the phone at a time that suits you. They will provide you with a free, no-obligation quotation where you will find out if equity release is right for you, how it could affect potential inheritance and how your entitlement to means-tested benefits could be affected – both now or in the future.

Equity release may involve a home reversion plan or a lifetime mortgage which is secured against your property. Request your personalised illustration to understand the features and risks.

Equity release requires paying off any existing mortgage. Any money released, plus accrued interest, is to be repaid upon death or moving into long-term care. Only if your case completes would a typical fee of £1,795 be payable.

Call FREE to request your equity release guide

0800 068 4086

or visit agepartnership.co.uk/ns

Age Partnership
The UK's No.1 Equity Release Advisor*

*UK's No.1 based on volume of plans, Touchstone data, 2018 – Q3 2020. Age Partnership Limited is authorised and regulated by the Financial Conduct Authority. FCA registered number 425432. Company registered in England and Wales No. 5265969. Company address: Age Partnership Limited, 2200 Century Way, Thorpe Park, Leeds, LS15 8ZB. VAT registration number 162 9355 92. Correct at time of print.

Or return this coupon to get your FREE guide to equity release to: Freepost Age Partnership

Title: .... Name: ....

Address: ....

Postcode: .... DOB: ....

Tel: .... Email: ....

Are you a homeowner? ☐

By supplying your address you are confirming that you are happy for Age Partnership to contact you via letter and email regarding products and services relevant to your enquiry. Age Partnership will contact you on the telephone number you are providing regarding your enquiry. For more information, please visit www.agepartnership.co.uk/privacy or to request to opt out at any time, email enquiries@agepartnership.com

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Age UK had the power to do more

“Barclays helped us be there for more older people when they needed us most”

To find out more about the impact in your area search **‘Barclays £100m COVID-19 Community Aid Package’.**

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